Appendix A

Acronyms Relevant to this Plan

Acronyms used in this Document

APA – Authorized Public Agency
BL – Business Loop
BMP – Best Management Practice
Caltrans – California Department of Transportation
CEA – County Enforcing Agent
CFR – Code of Federal Regulations
CWA – Clean Water Act
EPA – Environmental Protection Agency
IDEP – Illicit Discharge Elimination Plan
I- – Interstate
M- – Michigan Highway
MACDC – Michigan Association of County Drain Commissioners
MARS – Maintenance Activity Reporting System
MCL – Michigan Compiled Laws
MDEQ – Michigan Department of Environmental Quality
MDOT – Michigan Department of Transportation
MEA – Municipal Enforcing Agent
MEP – Maximum Extent Practicable
MPO – Metropolitan Planning Organization
MS4 – Municipal Separate Storm Sewer System
NPDES – National Pollutant Discharge Elimination System
NREPA – National Resources and Environmental Protection Act
O&M – Operation and Maintenance
PA – Public Act
PEP – Public Education Plan
PIPP – Pollution Incidence Prevention Plan
ROW – Right-of-Way
SWMP – Storm Water Management Plan
SWPPI – Storm Water Pollution Prevention Initiative
TMDL – Total Maximum Daily Load
TSC – Travel Service Center

Appendix B

Details of Initial BMP Selection and Evaluation

Evaluation of Best Management Practices for Michigan Department of Transportation

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INTRODUCTION

This report presents an overview of our assessments and investigations of appropriate structural and non-structural Best Management Practices (BMPs), which may be applicable to the Michigan Department of Transportation (MDOT) activities. In early 2000, a detailed matrix of the BMPs evaluated was presented to MDOT. The matrix was generated from detailed investigation of nation-wide urban and particularly Department of Transportation (DOT) BMP programs and pilot studies. Following review of this matrix, MDOT provided specific comments on each BMP. The short report presented here provides a brief summary of this initial investigation, a revised matrix based on the comments received from MDOT, and finally our recommendations.

ORIGINAL BMP MATRIX

The original list of BMPs presented to MDOT in early 2000, is attached to Appendix A. The matrix includes an overall and preliminary investigation of all possible urban runoff control BMPs, which could be applicable to MDOT activities. The matrix includes structural and non-structural BMPs, as well as BMPs currently being tested in pilot studies by California Department of Transportation (Caltrans). Information such as BMP description, limitations, benefits, pollutant removal efficiency (based on actual monitoring data), capital costs, and O&M costs is included. It should be noted that the information presented was retrieved from data available at the time of the matrix was generated. Costs presented are from 1999 unless indicated otherwise. The detailed information provided was intended to familiarize the reader with current nationwide practices, as well as pilot studies being conducted in evaluating Best Management Practices (BMPs).

REVISED BMP MATRIX

Following the review of the original BMP, MDOT provided specific comments on each BMP based on applicability to their operations and activities. As a result, many of the original BMPs were deleted from the original list. A revised list, including the approved BMPs and BMPs with limited use, is provided in Appendix B. The following is a brief outline of the structural BMPs, which MDOT did not object to and regarded as being appropriate for its activities:

Infiltration Trench is a gravel-filled trench designed to infiltrate storm water into the ground. Typically infiltration trenches can only capture a small amount of runoff, and therefore, may be designed to capture the first flush of the runoff event. For this reason, they are typically used with other BMPs, such as detention basins to control peak flows.

Ponds (Basins) are designed to capture a storm water runoff volume, hold this volume and infiltrate it into the ground over a period of days. Basins are typically not designed to retain a permanent pool of water.

Infiltration Drainfields are infiltration systems that capture a volume of runoff and infiltrate it into the ground. The system consists of a pretreatment structure, a manifold system, and a drainfield.

Concrete Grid Pavements are lattice grid structures with grassed or pervious material placed in the grid openings. Their use, however, is generally restricted to parking areas and driveways.

Wetlands (constructed) consist of a rectangular basin with a forebay and wetland vegetation area. The forebay traps floatables and the larger settleable solids, facilitating maintenance, as well as protecting the wetland vegetation.

Biofilters are of two types: swales and strips. Vegetated Swales are vegetated shallow channels with a dense stand of vegetation covering the side slopes and channel bottom that treat concentrated flows. Infiltration (Vegetative Filter) Strips are densely vegetated, uniformly graded areas that intercept sheet flow and are usually placed parallel to the contributing surface.

Dry Detention Basins are basins that are dry between storms. During a storm the basin fills. A bottom outlet releases the storm water slowly to provide time for sediments to settle.

Catch Basin Inlet Devices are devices that are inserted into storm drain inlets to filter, or absorb sediment, pollutants, and oil and grease. These devices are typically placed at locations with a high potential for contamination.

In addition to the above structural BMPs, MDOT approved of the following non-structural and erosion control BMPs:

Non-structural BMPs:

- Minimizing Effects from Highway Deicing
- Employee Training
- Litter Control
- Identify and Prohibit Illegal or Illicit Discharges to Storm Drains
- Street Sweeping
- Clean and Maintain Storm Drain Channels
- Clean and Maintain Storm Inlet and Catch Basins
- Snow and Ice Control Operations

Construction BMPs:

Temporary Seeding of Stripped Areas

- Mulching and Matting
- Plastic Covering

FURTHER RECOMMENDATIONS

In the time following the development of the original matrix, many of the listed BMPs have been the focus of further tests and have been additionally implemented in different urban watersheds throughout the nation. New and updated information on the effectiveness of these BMPs in removing urban type of pollutants may be available. It is recommended that the matrix be further updated with new information including updated costs, limitations, and advantages. The construction and maintenance costs should be further investigated based on updated information from manufacturers, as well as recent cost information for the similar constructions and maintenance activities in the area.

As mentioned previously, in the recent years Caltrans and UCLA have been conducting focused pilot studies on specific structural BMPs. The results from UCLA studies may be available now and Caltrans pilot study results should become available in late 2001, and 2002. It is recommended that MDOT take advantage of the results of these comprehensive pilot studies before spending resources on costly BMP efforts and programs.

In addition, it is recommended that the approved BMP matrix be used as a decision making tool for planning of appropriate BMPs. A decision-making process could be established to prioritize various sites with appropriate BMPs. The main criteria in the BMP prioritization should be water quality improvement. However, a ranking or weighing criteria could be applied to the limitations, benefits, pollutant removal efficiency, capital costs, and O&M costs and used in the decision-making process.

Finally, it is recommended that MDOT take a proactive role in testing some of the approved BMPs on site- specific areas before the actual implementation of them. Different types of investigations may be conducted to better understand MDOT pollutant load contributions, as well as pollutant behavior/dynamics. To gain further knowledge of BMP effectiveness in control of pollutants, the promising structural BMPs, are recommended to be further tested in controlled pilot studies.

APPENDIX A

Original BMP Matrix

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Infiltration - a family of treatment systems in which the majority of the runoff from small storms is infiltrated in the ground rather than discharged into a surface water body. (1)					
Infiltration Trench - is an excavated trench (3 to 12 feet deep), backfilled with stone aggregate, and lined with filter fabric. (23) It is used to treat a small portion of the runoff by detaining storm water for short periods until it percolates down to the groundwater table. (21) Useful life is usually around 10 years. (20)	*potential loss of infiltrative capacity. (1) *applicability depends on specific site characteristics/opportunities (slope, soil types, proximity to water table). (23) *potential groundwater contamination. (1) *not suitable for sites that contain chemical or hazardous material. (23) *may need to be preceded by appropriate pretreatment. (23) *relatively short life span. (23)	*efficient removal of pollutants. (1) *can recharge groundwater supplies. (2) *provides localized streambank erosion control. (2) *easy to fit into unutilized areas of development sites. (2) *an effective runoff control. (1) *increases baseflow in nearby streams. (23) *Low land use requirement. (20)	* nitrogen compounds 40% to 80%. (2) * phosphorus compounds 40% to 80%. (2) * combined nitrogen and phosphorus compounds 45% to 75% (depending on design). (8) * total suspended solids 75%. (20) *total phosphorous 60%. (20) * total nitrogen 55%. (20) *COD 65%. (20) * Lead 65%. (20) * Zinc 65%. (20)	* \$4,900/acre (prorated using ENR index from 1992 cost). (5) * \$3.6 to \$10.70/cubic feet storage (prorated using ENR index from 1986 cost). (20)	* \$1,800/acre/year (prorated using ENR index from 1992 cost). (5) * 9% of Capital Cost (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Pond (Basin) - consist of shallow, flat basins excavated in pervious ground, with inlet and outlet structures to regulate flow. (19) Useful Life is usually around 25-years. (20)	*potential loss of infiltrative capacity. (1) *low removal of dissolved pollutants in very coarse soils. (1) *possible nuisance (odor, mosquito). (2) *frequent maintenance requirement. (2) *risk of groundwater contamination. (1) * High land use requirement. (20)	*achieves high levels of particulate pollutant removal. (1) * can recharge groundwater supplies. (2) *an effective runoff control. (1) *can serve tributary areas up to 50 acres. (1) *provides localized streambank erosion control. (2) *cost effective. (2)	* nitrogen compounds 40% to 80%. (2) * phosphorus compounds 40% to 80%. (2) * combined nitrogen and phosphorus compounds 45% to 75% (depending on design). (8) * total suspended solids 75%. (20) *total phosphorous 65%. (20) * total nitrogen 60%. (20) *COD 65%. (20) * Lead 65%. (20) * Zinc 65%. (20)	* $36,900/million gallons (prorated using ENR index from 1992 cost). (5) * $0.60 to $1/cubic feet storage (prorated using ENR index from 1986 cost). (20)	* $1,200/million gallons/year (prorated using ENR index from 1992 cost). (5) * 7% of Capital Cost (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Porous Pavement - is an alternative to conventional pavement whereby runoff is diverted through a porous asphalt layer and into an underground stone reservoir. (10) Useful life is around 10 years. (20)	*potential loss of infiltrative capacity. (1) *75% failure rate due to clogging, resurfacing or just failure after construction. (10) *high maintenance – requires special vacuum sweeping or jet hosing. (10) *may require twice as much material as without porous pavement to achieve the needed strength. (10) *unsuitable in fill sites and steep slopes. (5) *potential risk of groundwater contamination. (1) *limited efficiency (6 months). (23)	*achieves high levels of pollutant removal. (1) *groundwater recharge. (2) *localize streambank erosion control. (2) *reduced land *consumption. (2) *elimination of curbs and gutters. (2) *safer driving surface. (2)	* nitrogen compounds 60% to 80%. (2) * phosphorus compounds 40% to 80%. (2) *nitrogen and phosphorus compounds 45% to 75% (depending on design). (8) * sediment 82 to 95%. (23) * total phosphorus compounds 65%. (23) * total nitrogen compounds 80 to 85%. (23) * total suspended solids 90%. (20) *total phosphorous. 65% (20) * total nitrogen 85%. (20) *COD 80%. (20) * Lead 100%. (20) * Zinc 100%. (20)	* $123,000/acre (prorated using ENR index from 1992 cost). (5) * $2.10/square feet (prorated using ENR index from 1987 cost) (incremental cost beyond the conventional asphalt pavement). (20)	* $250/acre/year (prorated using ENR index from 1992 cost). (5) * $0.14/square feet/year (prorated using ENR index from 1987 cost). (incremental cost beyond the conventional asphalt pavement). (20)
Concrete Grid Pavement – are lattice grid structures with grassed or pervious material placed in the grid openings. (1) Useful life is usually around 20 years. (20)	*require regular maintenance. (20) *not suitable for high traffic areas. (20) *potential groundwater contamination. (20) *only feasible where soil is permeable. (20)	*groundwater recharge. (20) *can provide peak flow control. (20)	*total nitrogen 90%. (20) * total phosphorus compounds 90%. (20) * total suspended solids 90%. (20) *COD 90%. (20) * Lead 90%. (20) * Zinc 90%. (20)	* $1.7 - $3.5/ft^2 (prorated using ENR index from 1981 cost) (incremental cost beyond the conventional asphalt pavement) (20)	* -$0.07/ft^2 feet (prorated using ENR index from 1981 cost) (incremental cost beyond the conventional asphalt pavement) (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Infiltration Drainfields – a system composed of a pretreatment structure, a manifold system, and a drainfield. (28)	*high maintenance when sediment loads are heavy. (28) *short life span if not well maintained. (28) *not suitable in regions with clay or silty soils. (28) *anaerobic conditions could clog the soil. (28) *potential groundwater contamination. (28)	*groundwater recharge. (28) *used to control runoff. (28)	* depends on design – little monitoring data currently available. Potentially 100% of pollutant could be prevented from entering surface water. (28)	Approx. $72,000 for a drainfield with dimensions: 100 ft long, 50 feet wide, 8 feet deep with 4 ft cover. (28)	
Wet Detention Ponds – small artificial impoundments with emergent wetland vegetation around the perimeter designed for the removal of particulate matter and dissolved nutrients. (19) Useful life is around 50 years. (20)	*maintaining oxygen supply in the pond. (1) *need of supplemental water to maintain water level. (1) *land constraints, infeasible in dense urban areas. (1) *local climate might affect biological uptake. (27) *eventual need for costly sediment removal. (2) *potential nuisance (mosquito, odor, algae). (2) *potential stratification and anoxic conditions. (27)	*achieves high levels of soluble and organic nutrient removal. (2) *creation of local wildlife habitat. (2) *decrease potential for downstream flooding. (27) *recreational and landscape amenities. (2) *decrease potential downstream stream bank erosion. (19)	* nitrogen 20% to 60%. (2) * phosphorus 40% to 80%. (2) * nitrogen & phosphorous 30% to 70% (depending on volume ratio). (8) * total suspended solids 50% to 90% (27) & 60% (20). * total phosphorus 30% to 90% (27) & 45% (20). * total nitrogen 35%. (20) * soluble nutrients 40% to 80%. (27) * lead 70% to 80% (27) & 75% (20). * zinc 40% to 50% (27) & 60% (20). * COD 40%. (20)	$17.50 to $35 per cubic meter of storage area (27)	3 to 5 percent of construction cost per year (27)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Wetlands - constructed wetlands are a single stage treatment system consisting of a forebay and micro pool with aquatic plants. They remove high levels of particulate, as well as some dissolved contaminants. (19) Useful life is around 50 years. (20)	*need of supplemental water to maintain water level. (1) *potential nutrient release in the winter. (19) *reduction in hydraulic capacity with plant growth. (19) *wetland area less than 2% of watershed area. (10) *potential groundwater contamination. (26) * high land requirements. (20)	*passive recreation and wildlife support. (1) *improve downstream water and habitat quality. (26) *flood attenuation. (26) *achieves high levels pollutant removal. (1)	* total suspended solids 67% (26) & 65% (20). * total phosphorus 49% (26) & 25% (20). * total nitrogen 28% (26) & 20% (20). * organic carbon 34%. (26) * COD 50%. (20) * petroleum hydrocarbons 87%. (26) * cadmium 36%. (26) * copper 41%. (26) * lead 62% (26) & 65% (20). * zinc 45% (26) & 35% (20). * bacteria 77%. (26)	$26,000 to $55,000 per acre of wetland. (26)	2 percent of construction cost per year. (26)
Biofilters - Systems designed to pass storm water runoff slowly over a vegetated surface in the form of a swale or strip to filter pollutants and to infiltrate the runoff. (19)					

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Bioretention – system designed to treat runoff. The runoff is conveyed as sheet flow to the treatment area, which consists of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants. (33)	*cold climate may hinder infiltrative capacity. (33) *not suitable for slopes greater than 20 percent. (33) *clogging may occur in high sediment load areas. (33)	*enhance quality of downstream water bodies. (33) *improves area's landscaping. (33) *provide shade and wind breaks. (33)	* total Phosphorus 70 to 83%. (33) * metals (copper, lead, zinc) 93 to 98%. (33) * TKN 68% to 80%. (33) * total suspended solids 90%. (33) * organics 90%. (33) * bacteria 90%. (33)	$500 for new development of a bioretention, $6,500 for retrofitting a site into a bioretention area (33)	

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Vegetated Swale – is a broad, shallow channel (typically trapezoidal shaped) with a dense stand of vegetation covering the side slopes and bottom. (29) Useful life is around 50 years. (20)	generally incapable of removing nutrients. (2) *can become drowning hazards, mosquito breeding areas. (29) not appropriate for steep topography, very flat grades. (29) tributary area limited to a maximum of 5 acres. (19) difficult to avoid channelization. (19) *ineffective in large storms due to high velocity flows. (29)	design to convey runoff of 2 year storm, with freeboard of 10 year storm. (19) * low land requirement. (20) suitable for small residential areas. (1) can removes particulate pollutants at rates similar to wet ponds. (1) *reduction of peak flows. (29) *lower capital cost. (29) *promotion of runoff infiltration. (29) * low land requirements. (20)	* nitrogen 0 to 60% (2) * total nitrogen 10%. (20) * phosphorus 0 to 60% (2) * total phosphorus 9% (29) & 20% (20). * COD 25%. (20) * oxygen demanding substances 67%. (29) * total suspended solids 81% (29) & 60% (20). * nitrate 38%. (29) * hydrocarbons 62%. (29) * cadmium 42%. (29) * lead 67% (29) & 70% (20). * zinc 71% (29) & 60% (20). * copper 51%. (29)	* $6.80 to $12.50 per linear foot (prorated using ENR index from 1987 cost). (29) * $10.80 to $63.40 per linear foot (prorated using ENR index from 1991 cost). (29) * typical total for a 1.5 ft. deep, 10 ft wide, 1,000 ft long Low - $8,100 Moderate - $14,870 High - $21,640 Prorated using ENR index from 1991 cost). (29)	* $0.73 - $0.95 per linear foot (prorated using ENR index from 1991 cost). (29) * $1/linear foot 9prorated using ENR index from 1987 cost). (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Infiltration (Vegetative Filter) Strip - are broad surfaces with a full grass cover that allows storm water to flow in a relatively thin sheets (21) Useful life is around 50 years (20).	*sheet flow may be difficult to attain. (1) *not appropriate for steep slopes. (19) *tributary area limited to 5 acres. (19)	*suitable for parking lots. (1) *slows runoff flow. (1) *removes particulate pollutants. (1)	* nitrogen 0 to 40%. (2) * phosphorus 0 to 40%. (2) * total suspended solids 65%. (20) * total phosphorous 40%. (20) * total nitrogen 40%. (20) * COD 40%. (20) * lead 45%. (20) * zinc 60%. (20)	* $3,100/acre (prorated using ENR index from 1992 cost). (5)	* $310/acre/yr (prorated using ENR index from 1992 cost). (5) * $139 to $1,100/acre/year (prorated using ENR index from 1987 cost). (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Extended Detention Basins - consist of a settling basin with an outlet sized to remove particulate matter by slowly releasing accumulated runoff over a 24 to 40 hour period. "Dry" detention basins may be designed to empty between usages. (19) Useful life is usually 50 years. (20)	*occasional nuisance in inundated portion. (19) *inability to vegetation may result in erosion and re-suspension. (1) *limited orifice diameter precludes use in small watersheds. (1) *requires differential in elevation at inlet and outlet. (1) *frequent sediment maintenance. (19) * High land requirement. (20)	*creation of local wildlife habitat. (2) *recreational use in inundated portion. (2) *can remove soluble nutrients by shallow marsh or permanent pool. (2) *suitable for sites over 10 acres. (10) *temporary storage of runoff. (1) *no need of supplemental water. (1) *protection for downstream channel erosion. (2)	* nitrogen 20% to 60%. (2) * phosphorus 20% to 80% (2) & 10% to 30%. (10) * nitrogen and phosphorus 30% to 70% (depending on volume ratio). (8) * soluble nutrients – low or negative. (10) * total suspended solids 45% (20) & 88% (44). * nitrate 15% (44). * nitrite 61% (44). * oil and grease 56%. (44) * fecal coliform 45%. (44) total petroleum hydrocarbons 17% to 20%. (44) * TKN 40%. (44) * ammonia 5%. (440 *total phosphorous 25% (20) & 57% (44). * total nitrogen 30%. (20) *COD 20% (20) & (44). * lead 20% (20) & 55% (44). * zinc 20% (20) & 47% (44). * chromium 68%. (44) * copper 37%. (44) * nickel 62%. (44)	$123,000/million gallons (prorated using ENR index from 1992 cost). (5)	* $1,230/million gallons/year (prorated using ENR index from 1992 cost). (5) * 4% of capital cost. (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Modular Treatment Systems StormTreat™ System (STS) – treatment technology consisting of a series of sedimentation chambers and constructed wetlands. The 9.5 feet diameter recycled polyethylene modular treats storm water with sedimentation chambers, where pollutants are removed through sedimentation and filtration, then the water is conveyed to a surrounding constructed wetland. Vegetation in the wetland varies depending on local conditions. Because the system is relatively new, there is no data available on lifetime of the system. It is estimated that the plants and the gravel in the system need to be replaced every 10-20 years. (32)	*may require modifications to function in different environments. (32) * relatively new and remains to be tested in different geographical locations.	*protect groundwater by removing pollutants prior to infiltration. (32) *high removal rates. (32) *spill containment feature. (32) *soil types and high water table won't limit effectiveness. (32)	* fecal coliform bacteria 97%. (32) * total suspended solids 99% (32) * COD 82%. (32) * total dissolved nitrogen 77%. (32) * phosphorus 90%. (32) * total petroleum hydrocarbons 90%. (32) * lead 77%. (32) * chromium 98%. (32) * zinc 90%. (32)	$4,900 per unit + $500 to $1,000 installation cost + $350 to $400 for additional material (32)	$80 to $120 per tank for removal of sediment (32)
Hydrodynamic Separators – are flow-through structures with a settling or separation unit to remove sediments and other pollutants that are widely used. With proper upkeep, useful life is over 30 years. (25)					
Downstream Defender™ - designed to capture settleable solids, floatables and oil and grease. It utilizes a sloping base, a dip plate and internal components to aid in pollutant removal. (25)	* requires frequent inspections and maintenance is site-specific. (25)		Can achieve 90% particle removal for flows from 0.75 cfs to 13 cfs (25)	$10,000 to $35,000 per pre cast unit (23)	

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Continuous Deflection Separator (CDS) - pre cast units placed downstream of freeway drain inlets to capture sediment and debris. These underground units create a vortex of water that allows water to escape through the screen, while contaminants are deflected into the sump. (21)	* suitable for gross pollutant removal. (21)	intended to screen litter, fine sand and larger particles. (21) act as a first screen influence for trash and debris, vegetative material, oil and grease, heavy metals. (21)	oil and grease – 77% (34)	\$2,300 to \$7,200 per cubic feet second capacity (23)	
Continuous Deflection Separator (CDS) with Sorbents. Application of different types of sorbents in the CDS units. *OARS*™ - is a rubber type off sorbent (34) *Rubberizer* – is composed of a mixture of hydrocarbon polymers and additives (34) *Aluminum Silicate*: - *Xsorb*™ is made from a natural blend of silica minerals, which when expanded in our unique manufacturing process, make a white granular material that absorbs spills instantly on contact (web) *Sponge Rok*™ - primarily sold as a soil bulking agent (34) *Nanofiber*™ - is a polypropylene adsorbent (34)	* requires frequent inspections and maintenance is site-specific. (25)	*sorbents remove many times their own weight (34) *could be used oil spill control. (34)	OARS: oil and grease - 82%, 83%, 86%, 94% (34) Rubberizer: oil and grease 86%. (34) Xsorb: oil and grease 79%. (34) Sponge Rok: oil and grease 41%. (34) Nanofiber: oil and grease 87%. (34)		

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Stormceptor® - This system is a stormwater interceptor that efficiently removes sediment and oil from stormwater runoff and stores these pollutants for safe and easy removal. Units are available in prefabricated sizes up to 12 feet in diameter by 6 to 8 feet deep. They re designed to trap and retain a variety of non-point source pollutants, using a by-pass chamber and treatment chamber. A fiberglass insert separates the upper (by-pass) and lower (separation/holding) chambers. (25)	* requires frequent inspections and maintenance is site-specific. (25)	*use for redevelopment projects of more than 2,500 sq. feet where there was no pervious storm water management. (25) *projects that double the impervious layer. (25) *easy to design in new or retrofit applications. (35) *inexpensive to service and maintain. (35) *internal bypass prevents release of trapped pollutants. (35) *Ideal for highways, industrial properties, gas stations, parking lots and sites where there is a potential for oil or chemical spills.	* total suspended solids 80%. (35) * free oils 95%. (35) * oil 98.5%. (36) * inorganic sediment 80%. (36) * organic sediment 70%. (36) * total suspended solids 51.5%. (36) * oil and grease 43.2%. (36) * zinc 39.1%. (36) * total organic carbon 31.4%. (36) * chemical oxygen demand 26.0%. (36) * lead 51.2%. (36) * chromium 40.7%. (36) * copper 21.5%. (36) * iron 52.7%. (36) * calcium 17.9%. (36)	$7,600 to $33,560 per unit (23)	$1,000/year per structure (23)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Vortechs™ - a major advancement in oil and grit separator technology, Vortechs units removes grit, contaminated sediments, heavy metals, and oily floating pollutants from surface runoff. It is a stormwater treatment system consisting of four structures to treat stormwater: a baffle wall, a grit chamber, an oil chamber and a flow control chamber. This system combines swirl-concentrator and flow-control technologies. (25)	*most effective when separation of heavy particulate or floatable from wet weather runoff. (25) *suspended solids are not effectively removed. (25) * requires frequent inspections and maintenance is site-specific. (25)	*suited for areas with limited land available (25) *good for "hotspots" such as gas stations (high concentrations). (25) *able to treat runoff flows from 1.6 cfs to 25 cfs. (25)	* total suspended solids 84%. (37)	$10,000 to $40,000 per unit (not including installation) (23)	
Multi-Chambered Treatment Trains (MCTT) - consist of a three treatment mechanisms in three different chambers. 1) catch basin - screening process to remove large, grit sized material, 2) settling chamber - removing settleable solids and associated constituents with plate separators and sorbent pads, 3) media filter - uses a combination of sorption (layers of sand and peat covered by filter fabric) and ion exchange for the removal of soluble constituents. (21)	*high maintenance – require renewing sorbent pads, removing sediment, replacing clogged media. (21)	*treats storm water at critical source areas with limited space. (21)	* toxicity 70% to 100%. (24) * chemical oxygen demand 0% to 100% (24) * total suspended solids 70% to 90% (24)	* approx. $375,000 to $900,000 (depending on drainage area)	
Media Filtration – these are usually two or three stage constructed treatment systems, composed of a pretreatment settling basin and a filter bed containing filter media (and a discharge chamber). (19)					

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Sand Filter - the filter is designed to hold and treat the first one half inch of runoff and the pollutant removal ability of the sand filter has been found to be very good. (3)	*not effective treating liquid or dissolved pollutants (19) routine maintenance requirement. (19) significant headloss. (19) severe clogging potential. (19) *media may be replaced 3 to 5 years. (30) *climate conditions may limit filter's performance. (30)	high removal rates for sediment, BOD, and fecal coliform bacteria. (30) *can reduce groundwater contamination. (30) requires less land, can be placed underground. (19) suitable for individual developments. (1) minimum depth of 18 inches. (1) tributary areas of up to 100 acres. (19)	* fecal coliform 76%. (30) * BOD 70 %. (30) * total suspended solids 70 %. (30) * total organic carbon 48%. (30) * total nitrogen 21%. (30) * total phosphorus 33%. (30) * Lead 45%. (30) * zinc 45%. (30) * iron 45%. (30)	* $18,500 (1 acre drainage area) (1997). (30) * $6,940 to $11,600 (less than 1 acre – cast in place) (prorated from 1997 prices using ENR index). (30)	* sand filter vault $1,790 (prorated from 1997 prices using ENR index). (18) * sand filter basin $3,370 (prorated from 1997 prices using ENR index). (18) * 5 percent of the initial construction cost. (30)
Activated Carbon - has long been used in the chemical process industry and in hazardous waste cleanup as an effective method for removing trace organics from a liquid. (3)	*heavy maintenance requirement. (19) *severe clogging potential. (19) *limited by the number of adsorption sites in the media. (3) *small net surface charge and ineffective at removing free hydrated metal ions. (3)	*can be placed underground. (19) *less space required. (1) *effective in removing trace organics from liquid. (3) *suitable for individual developments. (1)		* $1/lb or $315/cy (prorated from 1997 prices using ENR index). (18)	

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Composted Leaves - made from yard waste, primarily leaves, have been advertised to have a very high capacity for adsorbing heavy metals, oils, greases, nutrients and organic toxins due to the humic content of the compost. (3)	*heavy maintenance requirement. (19) *severe clogging potential. (19) *in some cases, negative removal efficiencies with increased loads have been reported. (22)	*can be placed underground. (19) *no vegetation required. (19) *smaller land area required. (3) *suitable for individual developments. (1)	* total suspended solids 84% (3), -155% to 72% (22). * petroleum hydrocarbons 87% (3), 4% to 64% (22). * chemical oxygen demand 67% (3), 32% to 38% (22). * total Phosphorus 40% (3) & -320% to 28% (22). * TKN –133% to 43%. (22) * fecal coliform 6% to 80%. (22) * oil and grease 0% to 44%. (22) * total petroleum hydrocarbons 33% to 64%. (22) * ammonia 41% to 64%. (22) * nitrate –172% to 7%. (22) * nitrite –233% to 29%. (22) * chromium 0% to 25%. (22) * copper 67% (3) & 4% to 9% (22). * zinc 88% (3) & 46% to 65% (22). * aluminum 87%. (3) * nickel 33% to 50%. (22) * lead 0% to 17%. (22) iron 89%. (3)	* $130/cy (prorated from 1997 prices using ENR index). (18) * $27,000 to treat 1 cfs (prorated from 1998 prices using ENR index). (22)	* $2,400/year (prorated from 1998 prices using ENR index). (22)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Peat Moss - is partially decomposed organic material, excluding coal that is formed from dead plant remains in water in the absence of air. The physical structure and chemical composition of peat is determined by the types of plants from which it is formed. Peat is physically and chemically complex and is highly organic. (3)	*heavy maintenance requirement. (19) *severe clogging potential. (19) *can have a high hydraulic conductivity. (3)	*can be placed underground. (19) *no vegetation required. (19) *smaller land area required. (3) *polar and has a high specific adsorption for dissolved solids. (3) *excellent natural capacity for ion exchange. (3) *excellent substrate for microbial growth and assimilation of nutrients and organic waste material. (3)		$25 to $105/cy (prorated from 1997 prices using ENR Index). (18)	
Peat-Sand Filter - man made filtration device, has good grass cover on the top underlain by twelve to eighteen inches of peat. The peat layer is supported by a 4-inch layer of peat and sand mixture, which supported by a 20 to 24 inch layer of fine to medium sand. Under the sand are gravel and the drainage pipe. (3)	*heavy maintenance requirement. (19) *severe clogging potential. (19)	*can be placed underground. (19) *less space required (1) *suitable for individual developments. (1) *works best during growing season as grass cover can provide additional nutrient removal. (3)	* suspended Solids 90% (3) & 80% (20). * total phosphorus 70% (3) & 50% (22). * total nitrogen 50% (3) & 35% (20). * BOD 90%. (3) * bacteria 90%. (3) * trace metals 80%. (3) * lead 60%. (20) * zinc 65%. (20) * COD 55%. (20)	$6.50 per cubic foot of material (prorated from 1990 prices using ENR index). (20)	7 % of construction cost. (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Water Quality Inlets – commonly known as oil/grit or oil/water separators. These devices typically consist of a series of chambers, a sedimentation chamber, an oil separation chamber and a discharge chamber. (31) Useful life is usually 50 years. (20)	*limited drainage area (1 acre or less). (31) *high sediment loads can interfere ability to separate oil and grease. (31) *limited hydraulic and residual storage. (31) *frequent maintenance. (31) *residual may be considered too toxic for landfill disposal. (31) *recommended oil/water separators are used for spill control as their primary application. (42) *re-suspension of pollutants. (36) * small flow capacity. (31)	*reduction of hydrocarbon contamination. (31) *effectively trap trash, debris, oil and grease (31) *ideal for small, highly impervious area. (31) *ideal for maintenance stations. (36) * low land requirement. (20)	* sediments 20% to 40%. (31) * efficiency directly proportional to discharge rate. (31) * total suspended solids 15% to 35%. (20) * total phosphorous 5%. (20) * total nitrogen 5% to 20%. (20) * COD 5%. (20) * lead 15%. (20) * zinc 5%. (20)	$5,900 to $18,900 for cast in place water quality inlets (prorated from 1993 prices using ENR Index). (31)	
Catch Basin Inlet Devices - devices that are inserted into storm drain inlets to filter or absorb sediment, pollutants, and oil and grease (21)	* not feasible for larger than 5 acres. (20)	* high removal efficiency for large particles and debris for pretreatment. (20) * low land requirement. (20) * flexibility for retrofit of existing systems. (20)			
Stream Guard Inserts - are sock-type inserts that allow collected water to filter through the geotextile fabric. (21)	*maintenance includes removal of sediment and debris. (21)	*configured to remove sediment, constituents adsorbed to sediment, and oil and grease. (21)		approx. $50,000 to $100,000 per catch basin. (21)	
Fossil Filter Inserts - are trough-type of inserts filled with granular amorphous alumina silicate media. Removes pollutants through sorption. (21)	*maintenance includes removal of sediment and debris. (21)	*configured to remove sediment, constituents adsorbed to sediment, and oil and grease. (21)		approx. $50,000 to $100,000 per catch basin. (21)	

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
OARS™ - is a rubber type of sorbent insert (34)			* free oil and grease 88% to 91%. (39) * emulsified oil and grease 3%. (39)		
Nanofiber™ - is a polypropylene adsorbent type of insert. (34)			* free oil and grease 86%, 92%, 78%, 85%. (39)		
Aluminum Silicate: *Xsorb*™ is made from a natural blend of silica minerals, which when expanded in the unique manufacturing process, makes a white granular material that absorbs spills instantly on contact. *Sponge Rok*™ - primarily sold as a soil bulking agent (34)			* free oil and grease 88%, 91%, 94%, 89%. (39) * emulsified oil and grease 0%. (39)		
Curb Inlet Drain Diaper Insert – sorbent type diaper placed at the catch basin insert. (40)				$125 per unit. (40)	
Storm Clenz Filter and Multi Cell Flow Through Filter – developed by Best Management Technologies, the filters are used typically in maintenance facilities and staging areas were sediment and hydrocarbons are present. (41)				* multi cell flow through filters - $786 to $1233 depending on pipe size (6” to 12”) * storm clenz filters - $339 to $702 depending on filter insert size. (41)	* flow through filter absorbents $24 to $44 depending on size. * storm clenz absorbents $24 to $ 54 depending on size. (41)
Some Examples of Temporary Erosion and Sediment Control BMPs – (typically used during construction activity)					

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Temporary Seeding of Stripped Areas - The establishment of a temporary vegetative cover on disturbed areas by seeding with rapidly growing plants. This provides temporary soil stabilization to areas, which would remain bare for more than seven days where permanent cover is not necessary or appropriate. (42)	*Temporary seeding is only viable when there is a sufficient window in time for plants to grow and establish cover. During the establishment period the bare soil should be protected with mulch and/or plastic covering. (42) *If sown on subsoil, growth may be poor unless heavily fertilized and limed Because over-fertilization can cause pollution of stormwater runoff, other practices such as mulching alone may be more appropriate. The potential for over-fertilization is an even worse problem in or near aquatic systems. (42) *Once seeded, areas cannot be used for heavy traffic. (42) *May require regular irrigation to flourish. Regular irrigation is not encouraged because of the expense and the potential for erosion in areas that are not regularly inspected. The use of low maintenance native species should be encouraged, and planting should be timed to minimize the need for irrigation. (42)	*This is a relatively inexpensive form of erosion control but should only be used on sites awaiting permanent planting or grading. Those sites should have permanent measures used. (42) *Vegetation will not only prevent erosion from occurring, but will also trap sediment in runoff from other parts of the site. (42) *Temporary seeding offers fairly rapid protection to exposed areas. (42)			

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Mulching and Matting - Application of plant residues or other suitable materials to the soil surface. This provides immediate protection to exposed soils during the period of short construction delays, or over winter months through the application of plant residues, or other suitable materials, to exposed soil areas. Mulches also enhance plant establishment by conserving moisture and moderating soil temperatures. Mulch helps hold fertilizer, seed, and topsoil in place in the presence of wind, rain, and runoff and maintains moisture near the soil surface. (42)	*Care must be taken to apply mulch at the specified thickness, and on steep slopes mulch must be supplemented with netting. (42) *Thick mulches can reduce the soil temperature, delaying seed germination. (42)	*Mulching offers instant protection to exposed areas. (42) *Mulches conserve moisture and reduce the need for irrigation. (42) *Neither mulching nor matting require removal; seeds can grow through them unlike plastic coverings. (42)			
Plastic Covering - The covering with plastic sheeting of bare areas, which need immediate protection from erosion. This provides immediate temporary erosion protection to slopes and disturbed areas that cannot be covered by mulching, in particular during the specified seeding periods. Plastic is also used to protect disturbed areas, which must be covered during short periods of inactivity to meet November 1 to March 31 cover requirements. Because of many disadvantages, plastic covering is the least preferred covering BMP. (42)	*There can be problems with vandals and maintenance. (42) *The sheeting will result in rapid, 100 percent runoff, which may cause serious erosion problems and/or flooding at the base of slopes unless the runoff is properly intercepted and safely conveyed by a collecting drain. This is strictly a temporary measure, so permanent stabilization is still required. *The plastic may blow away if it is not adequately overlapped and anchored. (42) *Ultraviolet light can cause some types of plastic to become brittle and easily torn. (42) *Plastic must be disposed of at a landfill; it is not easily degradable in the environment. (42)	*Plastic covering is a good method of protecting bare areas, which need immediate cover and for winter plantings. (42) *May be relatively quickly and easily placed. (42)			

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Alum Injection-Alum injection is the addition of alum to storm water which causes fine particles, suspended in the storm water, to flocculate and settle out. (45)	*Alum injection is an experimental practice. (45) *In addition to maintenance, alum injection requires ongoing operation. (45) *Alum injection cannot control storm water flows. (45) *Chemicals added during the alum injection process may have negative impacts on downstream waters. (45) *The precipitates produced from the alum treatment increase the solids that must be disposed of. (45)	Alum injection is a effective method to remove suspended particles in the storm water that may be difficult to remove via other methods.	TSS-95-99% removal (46) TP-85-95% removal (46) -37% removal (47) Ortho-Phos-90-95% (46) -42% (47) TN-60-70% (46) -52.2% (47) Fecal Coliform-99% (46) Heavy Metals-50-90% (46) Zinc-41% (47) Ammonia-(24.5)	$135,000 to $400,000 (45)	$6,500 to $25,000 per year
Green Parking-Green parking refers to several techniques applied together to reduce the impervious area. Green parking techniques limit the number of parking spaces, limit the dimensions of those spaces, utilize alternative pavers in overflow areas. Bioretention areas treat the runoff. (45)	The primary limitations include the applicability, cost, and maintenance of green parking. (45)	The benefits include the reduction of imperviousness and treatment of storm water. (45)	Bioretention is the primary method of removing pollutants in the grassed parking system. Bioretention removal rates are discussed previously in this table.	No Information	No Information

Nationwide Examples of Source Control (Non-Structural) Best Management Practices (BMPs)

Source Control (5)	Benefit (5)	Capital Cost (5)	O & M Cost (5)
Minimizing Effects from Highway Deicing			
Public Education (billing inserts, news releases, radio announcements, school programs)	*Can reduce improper disposal of paints and chemicals.	$200,000/yr (1992)	$257,000/yr (1992)
Employee Training – teaches employees about storm water management, potential sources of contaminants, and BMPs. (43)	*Low cost and easy to implement storm water management BMPs. (43)		
Litter Control	*Reduce potential clogging. *Proper disposal of paper, plastic and glass.	$20 per trash cans (1992)	$16/acre/yr (1992)
Recycling Program	*Reduction in potential clogging and harmful discharge.	$200,000/yr	$350,000 per 300,000 people
"No Littering" Ordinance	*Prevents litter from enter storm drain.	$20,000	potential self supporting
Identify and Prohibit Illegal or Illicit discharge to Storm Drain	*Halt hazardous and harmful discharge.	$2/acre (assumes 1 system monitored every 5 sq. miles)	$50/acre/yr (assumes TV inspection) $0.83/acre/yr
Street Sweeping – Two types of street sweepers are available for removal of solids from highway surfaces. The commonly used design is a mechanical street cleaner that combines a rotating gutter broom with a large cylindrical broom to carry the material onto a conveyor belt and into a hopper. The vacuum assisted sweepers, found to potentially remove more fine particles from the impervious surface, are impracticable due to their slow speed in highway maintenance operations. (42)	*Reduction in potential clogging storm drain material. *Some oil and grease control.	N/A	
Sidewalk Cleaning	*Reduction of material entering storm drain.	N/A	$60/acre/yr
Clean and Maintain Storm Drain Channels	*prevent erosion in channel. *improve capacity by removing sedimentation. *remove debris toxic to wildlife.	N/A	$21/acre/yr
Clean and Maintain Storm Inlet and Catch Basins - Inlets, catch basins, and manholes are to be periodically inspected and cleaned out using a vacuum truck. (42)	*removes sedimentation. *may prevent local flooding.	N/A	$21/acre/yr

Snow and Ice Control Operations - Snow control operations consist of removing accumulated snow from the traveled way, shoulders, widened areas and public highway approaches within the right-of-way. (42)	*Removes snow/ice before it requires ice control operations. (42)		
Clean and Inspect Debris Basin	*flood control. *proper drainage and prevent flooding.	N/A	$21/acre/yr
Spill Response and Prevention Plan (46)	*can be highly effective at reducing the risk of surface and ground water contamination. (46)	No Information	No Information
Used Oil Recycling Program (46)	*reduces the risk of groundwater and surface water contamination, but can become hazardous waste if mixed with other materials. (46)	N/A	Recovery service charge $79-$179 (46)
Materials Management Plan (46)	*Identifies hazardous and non-hazardous materials in the facility. (46) *Assures that all containers have labels. (46) *Identifies hazardous chemicals that require special handling, storage, and disposal (46)	No Information	No Information
BMP Inspection and Maintenance Plan (46)	*A regular inspection and maintenance program will maintain the effectiveness and structural integrity of the BMPs. (46)	N/A	$150-$9,000 depending on the BMP.
Storm Drain Stenciling (46)	*Educates the general public that the storm drain discharges into a natural waterbody. (46)	Mylar Stencils-$0.45 per lineal inch (46) Ceramic tiles $5-$6 each (46) Metal stencils-$100 or more (46)	No Information
Green Parking (46)	*Promotes infiltration and filtering of Stormwater. (46)	No Information	No Information
Alum Injection (46)	*Alum injected into stormwater forms precipitates that combine with heavy metals and phosphorus creating a floc. The floc is inert and stable. (46)	Cost ranges from $135,000 to $400,000 depending on the size of the watershed. (46)	$6,500 to $25,000 (46)

1. Camp Dresser & McKee, et al. 1993. *California Storm Water Best Management Handbook.* Prepared for Storm Water Quality Task Force. 4-8:4-77, 5-3:5-69.
2. Scheuler, Thomas R. 1987. *Controlling Urban Runoff: A Practice Manual for Planning and Designing Urban* BMP's. Prepared for Washington Metropolitan Water Resources Board. 2.11:2.14, 5.1:7.25.
3. Pitt, R. et al. "The Use of Special Inlet Devices, Filter Media, and Filter Fabrics for the Treatment of Storm Water." 9pp.
4. Eisenberg, Olivieri & Associates. 1996. *Guidance for Monitoring the Effectiveness of Storm Water Treatment Best Management Practices*. Prepared for the Bay Area Storm Water management Agencies Association. 5-6:5-7.
5. JMM. 1992 *A Study of Nationwide Costs to Implement Municipal Storm Water Best Management Practices*. Prepared for the Water Resources Committee American Public Works Association Southern California Chapter. 4-3:4-14.
6. Maine Department of Environmental Protection. *Environmental management: A Guide for the Town Officials*. 16, 27.
7. Denver regional Council of Government. *Nonpoint Source Demonstration Project*. 7:14.
8. Environmental Protection Agency, 1990. *Urban Targeting and BMP Selection*. 25:31.
9. Strecker, Eric W. 1993. *Assessment of Storm Drain Sources of Contaminants to Santa Monica Bay*. 21:28, 32.
10. Metropolitan Washington Council of Governments. 1992. *A Current Assessment of Urban Best management practices*. 7:13, 23:29, 55:69, 105:109.
11. Unocal. "More Down to Earth Talk from Unocal - Best Management Practices."
12. The Fertilizer Institute. 1985. Symposium: "Plant Nutrients Use and the Environment."
13. The Fertilizer Institute. 1988. *Best Management Practices*.
14. 1994. *Report of the Technical Advisory Committee for Plant Nutrient Management*. 17:18.
15. Virginia State Water Control Board Planning Bulletin 321. 1979. *Best Management Practices Handbook: Urban*. III-1:III-9, III-45:III-48, III-63:III-69, III-163:III-229.
16. California Department of Transportation Environmental Program. 1997. *Statewide Storm Water Management Plan*. B-14:B-53, C-1:C-22.
17. Caltrans Compost Storm Water Filters (CFSs), Bonita Canyon & North Hollywood Maintenance Yard. 1998. Table 9-15.
18. Minton, Gary R. "Storm Water Treatment by Media Filter." Dec. 11-12, 1997.
19. Ventura Countywide Storm Water Quality Management Program. "Draft Land Development Guidelines."
20. Environmental Protection Agency. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*.
21. Caltrans. Storm Water Program. *BMP Retrofit Pilot Studies, Technical Information*. 1999.
22. Caltrans. *Compost Storm Water Filters (CSFs), Bonita Canyon & North Hollywood Maintenance Yard 1997/1998 Wet Season, Post Sampling Summary Report*. 1998.
23. Environmental Protection Agency. 1999. *Infiltration Trench.* EPA 832-F-99-019.
24. Flan, Daryl R. and Himat Solanki. "Removal Efficiencies of Stormwater Control Structures."
25. Environmental Protection Agency. 1999. *Hydrodynamic Separators.* EPA 832-F-99-017.
26. Environmental Protection Agency. 1999. *Storm Water Wetlands.* EPA 832-F-99-025.

27. Environmental Protection Agency. 1999. *Wet Detention Ponds.* EPA 832-F-99-048.
28. Environmental Protection Agency. 1999. *Infiltration Drainfields.* EPA 832-F-99-018.
29. Environmental Protection Agency. 1999. *Vegetated Swales.* EPA 832-F-99-006.
30. Environmental Protection Agency. 1999. *Sand Filters.* EPA 832-F-99-007.
31. Environmental Protection Agency. 1999. *Water Quality Inlets.* EPA 832-F-99-029.
32. Environmental Protection Agency. 1999. *Modular Treatment Systems.* EPA 832-F-99-044.
33. Environmental Protection Agency. 1999. *Bioretention.* EPA 832-F-99-012.
34. Stenstrom, Michael K. and Sim-Lin Lau. "Oil and Grease Removal by Floating Sorbents in a CDS Device." University of California, Los Angeles, 1998.
35. Stormceptor Performance Testing Results. http://www.stormceptor.com/monitor.html
36. Westmount Shopping Centre and Conventry University Testing Results.
37. Caltrans. Highway Design Manual. *Chapter 890 – Storm Water Management*. Table 892.3.1999.
38. Allen, Vaikko P. Results from the Vortechs Stormwater Treatment System Monitoring Program at Del-Orme Publishing Company, Yarmouth, Maine. 1998.
39. Environmental Protection Agency and American Society of Civil Engineers. National Stormwater Best Management Practices (BMP) Database. Version 1.0, June 1999.
40. Lau, Sim-Lin and Michael K. Strenstrom. "Catch Basin Inserts to Reduce Pollution from Stormwater." Comprehensive Stormwater and Aquatic Ecosystem Management Conference, Auckland, NZ, February 22-26, 1999.
41. Petro-Marine Co. Curb Inlet Drain Diaper Insert. Contact Ronald Isaacson. 28 Buckley Road, Marlboro, NJ 07746.
42. Best Management Technologies Brochure. Contact Rod Butler. 23 Balwin Ave, Crockett, CA 94525.
43. Washington State Department of Transportation. Highway Runoff Manual. February 1995.
44. Environmental Protection Agency. 1999. *Employee Training.* EPA 832-F-99-010.
45. Caltrans. El Toro Detention Basin Storm Water Monitoring 1997/1998 Wet Season, Post Sampling Summary Report. 1998.
46. Environmental Protection Agency. 2002. www.epa.gov/npdes/menuofbmps/index.htm

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Los Angeles Area														
Bio Strip - are broad surfaces with a full grass cover that allows storm water to flow in a relatively thin sheets.	Altadena Maint Station	$218,000	1.7	1.0	1.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC1, REC2
Infiltration Trench -a trench is a depression used to treat small drainage areas by detaining storm water for short periods until it percolates to the groundwater table.	Altadena Maint Station	(built w/ bio strip)	1.7	1.0	1.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC1, REC2
Bio Strip	I-605/SR91	$193,000	0.5	1.0	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR

Caltrans - Best Management Practices Pilot Studies [1]															
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Bio Swale - are vegetated conveyance channels (typically trapezoidal shaped) wheere storm water flow passes through the grass at a specific depth.	I-605/SR91	(built w/ bio strip)	0.2	1.0	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR
Bio Swale	Cerritos Maint Station	$59,000	0.4	1.0	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR
Bio Swale	I-5/I-605	$97,000	0.7	1.0	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR
Bio Swale	I-605/Del Amo Ave	$124,000	0.7	1.0	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Infiltration Basin - a basin is a depression used to treat larger drainage areas by detaining storm water for short periods until it percolates to the groundwater table.	I-605/SR91	$273,000	4.2	1.0	0.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR
Drain Inlet Insert (stream guard)(a) - sock type inserts that allow collected water to filter through the geotextile fabric.	Las Flores Maint Station	$88,000	0.2	1.0	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD
Drain Inlet Insert (fossil filter) - trough type inserts filled with granular amorphous alumina silicate media.	Las Flores Maint Station	(built w/ DII (a))	0.8	1.0	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD
Drain Inlet Insert (stream guard)(a)	Rosemead Maint Station	$65,000	0.3	1.0	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, GWR, REC1, REC2, WARM
Drain Inlet Insert (fossil filter)	Rosemead Maint Station	(built w/ DII (a))	1.2	1.0	0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, GWR, REC1, REC2, WARM

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Drain Inlet Insert (stream guard)(a)	Foothill Maint Station	$68,000	0.2	1.0	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, GWR, MUN, REC1, REC2, WARM
Drain Inlet Insert (fossil filter)	Foothill Maint Station	(built w/ DII (a))	1.6	1.0	0.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, GWR, MUN, REC1, REC2, WARM
Extended Detention Basin* - is a depression lined with either vegetated soils or concrete.	I-5/I-605 Intersection	$142,000	6.8	1.0	5.3	1998-1999	2	-89 to -71	-84 to 23	N/A	N/A	-84 to -81	-83 to -92	RARE, REC1, REC2, SPWN, WILD, GWR
Extended Detention Basin*	I-605/SR91 Intersection	$137,000	0.8	1.0	1.2	1998-1999	3	-86 to -58	-54 to 2	N/A	N/A	15 to 222	-8 to 339	RARE, REC1, REC2, SPWN, WILD, GWR

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Media Filter* - designed removes fine sediment and particulate pollutants through two concrete lined vaults (sedimentation vault and filtering vault). Three filter types 1) Austin - open topped, 2) Delaware - closed topped, 3) canister - uses pearlite/zeolite media.	Eastern Reg. Maint Sta	$341,000	1.5	1.0	1.9	1998-1999	1	-34	112	N/A	N/A	10	108	WILD, GWR, REC2, WARM
Media Filter*	Foothill Maint Station	$479,000	1.8	1.0	3.0	1998-1999	2	-42 to –34	285 to 289	N/A	N/A	-7 to 83	42 to 140	WILD, GWR, MUN, REC1, REC2, WARM
Media Filter	Termination Park & Ride	$450,000	2.8	1.0	3.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR
Media Filter	Paxton Park & Ride	$331,000	1.3	1.0	1.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	GWR, REC2

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Multi-Chambered Treatment Train - Three chamber mechanism 1) catch basin, which functions primarily as a screening process, 2) settling chamber, which removes settleable solids with plate separators and sorption pads, 3) media filter, which uses a combination of sorption (through layers of sand and peat covered by filter material) and ion exchange.	Via Verde Park & Ride	$375,000	1.1	1.0	1.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, WET, GWR, REC1, REC2, WARM
Multi-Chambered Treatment Train	Metro Maint Station	$893,000	4.6	1.0	6.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	GWR, REC1, REC2, WARM
Multi-Chambered Treatment Train	Lakewood Park & Ride	$456,000	1.9	1.0	2.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Continuous Deflection Separator - a pre cast underground unit placed downstream of freeway drain inlets to capture sediment and debris. The unit creates a vortex of water that allows water to escape through screens, while contaminants are deflected into a sump, and later removed.	I-210/Orcas Ave	$62,000	1.1	1.0	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, GWR, REC1, REC2, WARM
Continuous Deflection Separator	I-210/Filmore St	$63,000	2.5	1.0	0.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, GWR, REC1, REC2, WARM
Media Filter (compost)[2]	N. Hollywood Maint Sta	$40,000	3.0	0.7	1.0	1997-1998	5	-155	7	29	38 [4]	28 [4]	43	-
Media Filter (compost)[2]	Bonita Canyon		1.7	0.8	6.0	1997-1998	5	72	-172	-233	-1633	-320	-133	-
Extended Detention Basin [3]	El Toro		68	0.8	30.4	1997-1998	5	88	15	61	22	57	40	RARE, REC1, REC2, SPWN, WILD, GWR

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
San Diego Area														
Extended Detention Basin	I-5/Manchester (east)	$369,000	4.8	1.3	4.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC1, REC2, BIOL, EST, WILD, RARE, MAR, MIGR
Extended Detention Basin	I-5/SR56	$166,000	5.3	1.3	5.7	1998-1999	5	23 to 80	-100 to 64	-	-	-65 to 68	-84 to 43	BIOL, EST, MAR, MIGR, RARE, REC1, REC2, SHELL, WILD
Extended Detention Basin	I-15/SR78	$855,000	13.4	1.9	9.5	1998-1999	4	45 to 72	-240 to 58	-	-	-299 to -62	-101 to 19	AGR, COLD, MUN, REC1, REC2, WARM, WILD
Infiltration Basin	I-5/La Costa (west)	$241,000	3.2	1.3	3.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	BIOL, EST, MAR, MIGR, RARE, REC1, REC2, WARM

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Wet Basin - a basin consisting of a permanent pool of water surrounded by a variety of wetland plant species.	I-5/La Costa (east)	$694,000	4.2	1.3	2.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC1, REC2, BIOL, EST, WILD, RARE, MAR, MIGR
Media Filter (pearolite/zeolite)	Kearny Mesa Maint Sta	$340,000	1.5	0.9	2.7	1998-1999	3	-27 to 20	5 to 29	-	-	-115 to 46	5 to 32	REC2, WARM, WILD
Media Filter (sand type II)	Escondido Maint Station	$451,000	0.8	1.0	2.2	1998-1999	3	0 to 66	11 to 70	-	-	-23 to 70	56 to 84	MUN, AGR, REC1, REC2, WARM COLD, WILD
Media Filter (sand type I)	La Costa Park & Ride	$242,000	2.8	0.9	2.3	1998-1999	3	54 to 98	-98 to 4	-	-	-113 to 26	-28 to 38	BIOL, EST, AMR, MIGR, RARE, REC1, REC2, WARM
Media Filter (sand type I)	SR78/I-5 Park & Ride	$231,000	0.8	1.0	2.7	1998-1999	2	54	-313	-	-	-7 to 28	7 to 11	BIOL, MAR, RARE, REC1, REC2, WARM, WILD

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Bio Swale	SR78/Melrose Dr	$156,000	2.4	1.2	6.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	AGR, OMD, REC1, REC2, WARM, WILD
Bio Swale	I-5/Palomar Airport Rd	$142,000	2.3	N/A	3.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC2, WARM, WILD
Bio Strip	Carlsbad Maint Sta (west)	$196,000	0.7	N/A	1.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC2, WARM, WILD
Infiltration Trench/Strip	Carlsbad Maint Sta (east)	(built w/ bio strip)	1.7	1.3	2.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC2, WARM, WILD

1. Caltrans. BMP Retrofit Pilot Studies: Technical Information. 1999. This information is preliminary and will be verified later.
2. Caltrans. Compost Storm Water Filters (CSFs), Bonita Canyon & North Hollywood Maintenance Yard, Storm Water Monitoring. 1998.3. Caltrans. El Toro Detention Basin, Storm Water Monitoring. 1998.
4. Dissolved Phosphorus higher than Total Phosphorus concentrations, due to results from storm 4. Without storm 4, efficiencies are -36% for dissolved phosphorus and 7% for total phosphorus.
N/A - Not Available at this time. * Preliminary Information.

APPENDIX B

MDOT APPROVED BMPS

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Infiltration - a family of treatment systems in which the majority of the runoff from small storms is infiltrated in the ground rather than discharged into a surface water body. (1)					
Infiltration Trench - is an excavated trench (3 to 12 feet deep), backfilled with stone aggregate, and lined with filter fabric. (23) It is used to treat a small portion of the runoff by detaining storm water for short periods until it percolates down to the groundwater table. (21) Useful life is usually around 10 years. (20)	*potential loss of infiltrative capacity. (1) *applicability depends on specific site characteristics/opportunities (slope, soil types, proximity to water table). (23) *potential groundwater contamination. (1) *not suitable for sites that contain chemical or hazardous material. (23) *may need to be preceded by appropriate pretreatment. (23) *relatively short life span. (23)	*efficient removal of pollutants. (1) *can recharge groundwater supplies. (2) *provides localized streambank erosion control. (2) *easy to fit into unutilized areas of development sites. (2) *an effective runoff control. (1) *increases baseflow in nearby streams. (23) *Low land use requirement. (20)	* nitrogen compounds 40% to 80%. (2) * phosphorus compounds 40% to 80%. (2) * combined nitrogen and phosphorus compounds 45% to 75% (depending on design). (8) * total suspended solids 75%. (20) *total phosphorous 60%. (20) * total nitrogen 55%. (20) *COD 65%. (20) * Lead 65%. (20) * Zinc 65%. (20)	* $4,900/acre (prorated using ENR index from 1992 cost). (5) * $3.6 to $10.70/cubic feet storage (prorated using ENR index from 1986 cost). (20)	* $1,800/acre/year (prorated using ENR index from 1992 cost). (5) * 9% of Capital Cost (20)
Pond (Basin) - consist of shallow, flat basins excavated in pervious ground, with inlet and outlet structures to regulate flow. (19) Useful Life is usually around 25-years. (20)	*potential loss of infiltrative capacity. (1) *low removal of dissolved pollutants in very coarse soils. (1) *possible nuisance (odor, mosquito). (2) *frequent maintenance requirement. (2) *risk of groundwater contamination. (1) * High land use requirement. (20)	*achieves high levels of particulate pollutant removal. (1) * can recharge groundwater supplies. (2) *an effective runoff control. (1) *can serve tributary areas up to 50 acres. (1) *provides localized streambank erosion control. (2) *cost effective. (2)	* nitrogen compounds 40% to 80%. (2) * phosphorus compounds 40% to 80%. (2) * combined nitrogen and phosphorus compounds 45% to 75% (depending on design). (8) * total suspended solids 75%. (20) *total phosphorous 65%. (20) * total nitrogen 60%. (20) *COD 65%. (20) * Lead 65%. (20) * Zinc 65%. (20)	* $36,900/million gallons (prorated using ENR index from 1992 cost). (5) * $0.60 to $1/cubic feet storage (prorated using ENR index from 1986 cost). (20)	* $1,200/million gallons/year (prorated using ENR index from 1992 cost). (5) * 7% of Capital Cost (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Concrete Grid Pavement – are lattice grid structures with grassed or pervious material placed in the grid openings. (1) Useful life is usually around 20 years. (20)	*require regular maintenance. (20) *not suitable for high traffic areas. (20) *potential groundwater contamination. (20) *only feasible where soil is permeable. (20)	*groundwater recharge. (20) *can provide peak flow control. (20)	*total nitrogen 90%. (20) * total phosphorus compounds 90%. (20) * total suspended solids 90%. (20) *COD 90%. (20) * Lead 90%. (20) * Zinc 90%. (20)	* $1.7 - $3.5/ft^2 (prorated using ENR index from 1981 cost) (incremental cost beyond the conventional asphalt pavement) (20)	* -$0.07/ft^2 feet (prorated using ENR index from 1981 cost) (incremental cost beyond the conventional asphalt pavement) (20)
Infiltration Drainfields – a system composed of a pretreatment structure, a manifold system, and a drainfield. (28)	*high maintenance when sediment loads are heavy. (28) *short life span if not well maintained. (28) *not suitable in regions with clay or silty soils. (28) *anaerobic conditions could clog the soil. (28) *potential groundwater contamination. (28)	*groundwater recharge. (28) *used to control runoff. (28)	* depends on design – little monitoring data currently available. Potentially 100% of pollutant could be prevented from entering surface water. (28)	Approx. $72,000 for a drainfield with dimensions: 100 ft long, 50 feet wide, 8 feet deep with 4 ft cover. (28)	
Wetlands - constructed wetlands are a single stage treatment system consisting of a forebay and micro pool with aquatic plants. They remove high levels of particulate, as well as some dissolved contaminants. (19) Useful life is around 50 years. (20)	*need of supplemental water to maintain water level. (1) *potential nutrient release in the winter. (19) *reduction in hydraulic capacity with plant growth. (19) *wetland area less than 2% of watershed area. (10) *potential groundwater contamination. (26) * high land requirements. (20)	*passive recreation and wildlife support. (1) *improve downstream water and habitat quality. (26) *flood attenuation. (26) *achieves high levels pollutant removal. (1)	* total suspended solids 67% (26) & 65% (20). * total phosphorus 49% (26) & 25% (20). * total nitrogen 28% (26) & 20% (20). * organic carbon 34%. (26) * COD 50%. (20) * petroleum hydrocarbons 87%. (26) * cadmium 36%. (26) * copper 41%. (26) * lead 62% (26) & 65% (20). * zinc 45% (26) & 35% (20). * bacteria 77%. (26)	$26,000 to $55,000 per acre of wetland. (26)	2 percent of construction cost per year. (26)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Biofilters - Systems designed to pass storm water runoff slowly over a vegetated surface in the form of a swale or strip to filter pollutants and to infiltrate the runoff. (19)					
Vegetated Swale – is a broad, shallow channel (typically trapezoidal shaped) with a dense stand of vegetation covering the side slopes and bottom. (29) Useful life is around 50 years. (20)	*generally incapable of removing nutrients. (2) *can become drowning hazards, mosquito breeding areas. (29) *not appropriate for steep topography, very flat grades. (29) *tributary area limited to a maximum of 5 acres. (19) *difficult to avoid channelization. (19) *ineffective in large storms due to high velocity flows. (29)	*design to convey runoff of 2 year storm, with freeboard of 10 year storm. (19) * low land requirement. (20) *suitable for small residential areas. (1) *can removes particulate pollutants at rates similar to wet ponds. (1) *reduction of peak flows. (29) *lower capital cost. (29) *promotion of runoff infiltration. (29) * low land requirements. (20)	* nitrogen 0 to 60% (2) * total nitrogen 10%. (20) * phosphorus 0 to 60% (2) * total phosphorus 9% (29) & 20% (20). * COD 25%. (20) * oxygen demanding substances 67%. (29) * total suspended solids 81% (29) & 60% (20). * nitrate 38%. (29) * hydrocarbons 62%. (29) * cadmium 42%. (29) * lead 67% (29) & 70% (20). * zinc 71% (29) & 60% (20). * copper 51%. (29)	* $6.80 to $12.50 per linear foot (prorated using ENR index from 1987 cost). (29) * $10.80 to $63.40 per linear foot (prorated using ENR index from 1991 cost). (29) * typical total for a 1.5 ft. deep, 10 ft wide, 1,000 ft long Low - $8,100 Moderate - $14,870 High - $21,640 Prorated using ENR index from 1991 cost. (29)	* $0.73 - $0.95 per linear foot (prorated using ENR index from 1991 cost). (29) * $1/linear foot 9prorated using ENR index from 1987 cost). (20)
Infiltration (Vegetative Filter) Strip - are broad surfaces with a full grass cover that allows storm water to flow in a relatively thin sheets (21) Useful life is around 50 years (20).	*sheet flow may be difficult to attain. (1) *not appropriate for steep slopes. (19) *tributary area limited to 5 acres. (19)	*suitable for parking lots. (1) *slows runoff flow. (1) *removes particulate pollutants. (1)	* nitrogen 0 to 40%. (2) * phosphorus 0 to 40%. (2) * total suspended solids 65%. (20) * total phosphorous 40%. (20) * total nitrogen 40%. (20) * COD 40%. (20) * lead 45%. (20) * zinc 60%. (20)	* $3,100/acre (prorated using ENR index from 1992 cost). (5)	* $310/acre/yr (prorated using ENR index from 1992 cost). (5) * $139 to $1,100/acre/year (prorated using ENR index from 1987 cost). (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Dry Detention Basins - consist of a settling basin with an outlet sized to remove particulate matter by slowly releasing accumulated runoff over a 24 to 40 hour period. “Dry” detention basins may be designed to empty between usages. (19) Useful life is usually 50 years. (20)	*occasional nuisance in inundated portion. (19) *inability to vegetation may result in erosion and re-suspension. (1) *limited orifice diameter preclude use in small watersheds. (1) *requires differential in elevation at inlet and outlet. (1) *frequent sediment maintenance. (19) * High land requirement. (20)	*creation of local wildlife habitat. (2) *recreational use in inundated portion. (2) *can remove soluble nutrients by shallow marsh or permanent pool. (2) *suitable for sites over 10 acres. (10) *temporary storage of runoff. (1) *no need of supplemental water. (1) *protection for downstream channel erosion. (2)	* nitrogen 20% to 60%. (2) * phosphorus 20% to 80% (2) & 10% to 30%. (10) * nitrogen and phosphorus 30% to 70% (depending on volume ratio). (8) * soluble nutrients – low or negative. (10) * total suspended solids 45% (20) & 88% (44). * nitrate 15% (44). * nitrite 61% (44). * oil and grease 56%. (44) * fecal coliform 45%. (44) total petroleum hydrocarbons 17% to 20%. (44) * TKN 40%. (44) * ammonia 5%. (440 *total phosphorous 25% (20) & 57% (44). * total nitrogen 30%. (20) *COD 20% (20) & (44). * lead 20% (20) & 55% (44). * zinc 20% (20) & 47% (44). * chromium 68%. (44) * copper 37%. (44) * nickel 62%. (44)	$123,000/million gallons (prorated using ENR index from 1992 cost). (5)	* $1,230/million gallons/year (prorated using ENR index from 1992 cost). (5) * 4% of capital cost. (20)
Catch Basin Inlet Devices - devices that are inserted into storm drain inlets to filter or absorb sediment, pollutants, and oil and grease (21)	* not feasible for larger than 5 acres. (20)	* high removal efficiency for large particles and debris for pretreatment. (20) * low land requirement. (20) * flexibility for retrofit of existing systems. (20)			

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Curb Inlet Drain Diaper Insert – sorbent type diaper placed at the catch basin insert. (40)				$125 per unit. (40)	
Some Examples of Temporary Erosion and Sediment Control BMPs – (typically used during construction activity)					

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Temporary Seeding of Stripped Areas - The establishment of a temporary vegetative cover on disturbed areas by seeding with rapidly growing plants. This provides temporary soil stabilization to areas which would remain bare for more than seven days where permanent cover is not necessary or appropriate. (42)	*Temporary seeding is only viable when there is a sufficient window in time for plants to grow and establish cover. During the establishment period the bare soil should be protected with mulch and/or plastic covering. (42) *If sown on subsoil, growth may be poor unless heavily fertilized and limed Because over-fertilization can cause pollution of stormwater runoff, other practices such as mulching alone may be more appropriate. The potential for over-fertilization is an even worse problem in or near aquatic systems. (42) *Once seeded, areas cannot be used for heavy traffic. (42) *May require regular irrigation to flourish. Regular irrigation is not encouraged because of the expense and the potential for erosion in areas that are not regularly inspected. The use of low maintenance native species should be encouraged, and planting should be timed to minimize the need for irrigation. (42)	*This is a relatively inexpensive form of erosion control but should only be used on sites awaiting permanent planting or grading. Those sites should have permanent measures used. (42) *Vegetation will not only prevent erosion from occurring, but will also trap sediment in runoff from other parts of the site. (42) *Temporary seeding offers fairly rapid protection to exposed areas. (42)			

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Mulching and Matting - Application of plant residues or other suitable materials to the soil surface. This provides immediate protection to exposed soils during the period of short construction delays, or over winter months through the application of plant residues, or other suitable materials, to exposed soil areas. Mulches also enhance plant establishment by conserving moisture and moderating soil temperatures. Mulch helps hold fertilizer, seed, and topsoil in place in the presence of wind, rain, and runoff and maintains moisture near the soil surface. (42)	*Care must be taken to apply mulch at the specified thickness, and on steep slopes mulch must be supplemented with netting. (42) *Thick mulches can reduce the soil temperature, delaying seed germination. (42)	*Mulching offers instant protection to exposed areas. (42) *Mulches conserve moisture and reduce the need for irrigation. (42) *Neither mulching nor matting require removal; seeds can grow through them unlike plastic coverings. (42)			
Spill Response and Prevention Plan (46)	*Requires a well-planned and clearly defined plan. *May require training *Equipment must be readily available. (46)	*can be highly effective at reducing the risk of surface and ground water contamination. (46)	N/A	No Information	No Information
Used Oil Recycling Program (46)	*Oil may easily become contaminated during collection making it a hazardous waste. (46)	*reduces the risk of groundwater and surface water contamination, but can become hazardous waste if mixed with other materials. (46)	N/A	N/A	Recovery service charge $79-$179 (46)
Materials Management Plan (46)	No Information	*Identifies hazardous and non-hazardous materials in the facility. (46) *Assures that all containers have labels. (46) *Identifies hazardous chemicals that require special handling, storage, and disposal (46)	N/A	No Information	No Information

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
BMP Inspection and Maintenance Plan (46)	Materials needed for emergency structural repairs may not be easily obtainable and may require stockpiling. (46)	*A regular inspection and maintenance program will maintain the effectiveness and structural integrity of the BMPs. (46)		N/A	$150-$9,000 depending on the BMP. (46)
Storm Drain Stenciling (46)	*Paint will weather away a short period of time and decals may need replaced if vandalized or improperly installed. (46)	*Educates the general public that the storm drain discharges into a natural waterbody. (46)	N/A	Mylar Stencils-$0.45 per lineal inch (46) Ceramic tiles $5-$6 each (46) Metal stencils-$100 or more (46)	No Information
Green Parking (46) This BMP will be experimental for MDOT until it is proven valuable and cost effective.	*Applicability(46) *Cost *Maintenance	*Promotes infiltration and filtering of Stormwater. (46)	N/A	No Information	No Information
Alum Injection (46) This BMP will be experimental for MDOT until it is proven valuable and cost effective.	*Experimental practice(46) *Involves on-going operation in addition to maintenance(46) *Does not control flows(46) *Chemicals may have negative impacts downstream(46) *Precipitates must be disposed of. (46)	*Alum injected into stormwater forms precipitates that combine with heavy metals and phosphorus creating a floc. The floc is inert and stable. (46)	Removal efficiency varies greatly by study and pollutant. The removal efficiency is uncertain at this time. (46)	Cost ranges from $135,000 to $400,000 depending on the size of the watershed. (46)	$6,500 to $25,000 (46)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Plastic Covering - The covering with plastic sheeting of bare areas, which need immediate protection from erosion. This provides immediate temporary erosion protection to slopes and disturbed areas that cannot be covered by mulching, in particular during the specified seeding periods. Plastic is also used to protect disturbed areas, which must be covered during short periods of inactivity to meet November 1 to March 31 cover requirements. Because of many disadvantages, plastic covering is the least preferred covering BMP. (42)	*There can be problems with vandals and maintenance. (42) *The sheeting will result in rapid, 100 percent runoff, which may cause serious erosion problems and/or flooding at the base of slopes unless the runoff is properly intercepted and safely conveyed by a collecting drain. This is strictly a temporary measure, so permanent stabilization is still required. *The plastic may blow away if it is not adequately overlapped and anchored. (42) *Ultraviolet light can cause some types of plastic to become brittle and easily torn. (42) *Plastic must be disposed of at a landfill; it is not easily degradable in the environment. (42)	*Plastic covering is a good method of protecting bare areas, which need immediate cover and for winter plantings. (42) *May be relatively quickly and easily placed. (42)			

Nationwide Examples of Source Control (Non-Structural) Best Management Practices (BMPs)

Source Control (5)	Benefit (5)	Capital Cost (5)	O & M Cost (5)
Minimizing Effects from Highway Deicing			
Employee Training – teaches employees about storm water management, potential sources of contaminants, and BMPs. (43)	*low cost and easy to implement storm water management BMPs. (43)		
Litter Control	*Reduce potential clogging. *proper disposal of paper, plastic and glass.	$20 per trash cans (1992)	$16/acre/yr (1992)
Identify and Prohibit Illegal or Illicit discharge to Storm Drain	*halt hazardous and harmful discharge.	$2/acre (assumes 1 system monitored every 5 sq. miles)	$50/acre/yr (assumes TV inspection)
Street Sweeping - Two types of street sweepers are available for removal of solids from highway surfaces. The commonly used design is a mechanical street cleaner that combines a rotating gutter broom with a large cylindrical broom to carry the material onto a conveyor belt and into a hopper. The vacuum assisted sweepers, found to potentially remove more fine particles from the impervious surface, are impracticable due to their slow speed in highway maintenance operations. (42)	*reduction in potential clogging storm drain material. *some oil and grease control.	N/A	$0.83/acre/yr
Clean and Maintain Storm Drain Channels	*prevent erosion in channel. *improve capacity by removing sedimentation. *remove debris toxic to wildlife.	N/A	$21/acre/yr
Clean and Maintain Storm Inlet and Catch Basins - Inlets, catch basins, and manholes are to be periodically inspected and cleaned out using a vacuum truck. (42)	*removes sedimentation. *may prevent local flooding.	N/A	$21/acre/yr

Snow and Ice Control Operations - Snow control operations consist of removing accumulated snow from the traveled way, shoulders, widened areas and public highway approaches within the right-of-way. (42)	*removes snow/ice before it requires ice control operations. (42)		

Appendix C

Watershed and/or Local Stream Organizations

River/Watershed Groups with Interest in the Five Phase I Communities
Ann Arbor, Flint, Grand Rapids, Sterling Heights, Warren

Clinton River
Clinton River Watershed Council
Jessica Pitelka Opfer, Executive Director
Brett E. Levin, Education Director
1970 E. Auburn Road
Rochester Hills, MI 48307-4803
(248) 853-9580
(248) 853-0486 fax
jesica@crwc.org
educator@crwc.org

Clinton River RAP
William Smith
49 Breitmeyer
Mt. Clemens, MI 48043
(810) 468-4028

Flint River
Flint River Watershed Coalition
Glenn Lefeber, Executive Director
Dorothy Gonzales, Public Relations Chair
Center for Applied Environmental Research
432 N. Saginaw Street
Suite 805
Flint, MI 48502
(810) 257-3190 or 810-767-6490
(810) 257-3810 fax
dgonzale@co.genesee.mi.us
flint.river.org

Partnership for the Saginaw Bay Watershed
William Wright
c/o Saginaw County Planning
400 Court Street
Saginaw, MI 48602
(517) 797-6800
(517) 797-6947 fax

Saginaw River/Bay RAP
Dennis Zimmerman
716 E. Forest Blvd.
P.O. Box 325
Lake George, MI (517) 588-9343
(517) 588-2574 fax

The WETNET Project
Goodrich Middle/High Schools
8029 S. Gale Road
Goodrich, MI 48438
(810) 636-2550
(810) 636-2253 fax
twheatle@genesee.freenet.org

Grand River
Robert B. Annis Water Resources Institute
Grand Valley State University
One Campus Drive
Allendale, MI 49401
(616) 895-3749

Bear Creek Watershed Project
Barbara Scott
Robert B. Annis Water Resources Institute
Grand Valley State University
One Campus Drive
Allendale, MI 49401
(616) 895-3789

West Michigan Environmental Action Council
1514 Wealthy SE
Grand Rapids, MI 49506
(616) 451-3051
info@wmeac.org
http://www.wmeac.org

York Creek
Frank Walsh
Robert B. Annis Water Resources Institute
Grand Valley State University
One Campus Drive
Allendale, MI 4940
(616) 895-3722

River/Watershed Groups with Interest in the Five Phase I Communities
Ann Arbor, Flint, Grand Rapids, Sterling Heights, Warren
Continued

Huron River
Huron River Watershed Council
Laura Rubin, Executive Director
1100 N. Main Street
Suite 210
Ann Arbor, MI 48104
(734) 769-5123
(734) 998-0163 fax
lrubin@hrwc.org
comnet.org/hrwc/

Allens Creek Watershed Group
Rita or Vince Caruso
(734) 668-0497

Fleming Creek Advisory Council
Meroe Kericher
(734) 459-5386

Malletts Creek Association
Jesse Gordon (734) 971-9018

Michigan Natural Areas Council
Teresa Chase, Sylvia M. Taylor, Ph.D.
c/o Matthaei Botanical Gardens
1800 N. Dixboro Road
Ann Arbor, MI 48109-9741
(734) 461-9390
mnac@cyberspace.org

Appendix D

IDEP Field Protocol Manual

MICHIGAN DEPARTMENT OF TRANSPORTATION

Illicit Discharge Elimination Program

FIELD PROTOCOL MANUAL

Prepared by:

TETRA TECH MPS

September 2002

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INTRODUCTION

PHASE I ILLICIT DISCHARGE ELIMINATION REQUIREMENTS

The United States Environmental Protection Agency's (EPA) Phase I Storm Water regulations require all regulated MS4 communities and agencies to address six minimum measures. Among these six measures there are the Illicit Discharge Detection and Elimination Minimum Control Measure. Under the regulations, this measure must include the following:

- A storm sewer system map showing the location of all outfalls and the names and location of all waters of the United States that receive discharges from those outfalls.
- Through an ordinance, or other regulatory mechanism, a prohibition on non-storm water discharges into the MS4 community, and appropriate enforcement procedures and actions.
- A plan to detect and address non-storm water discharges, including illegal dumping, into the MS4 community.
- The education of public employees, businesses, and the general public about the hazards associated with illegal discharges and improper disposal of waste.
- The determination of appropriate best management practices (BMPs) and measurable goals for this minimum control measure.

WHAT IS AN ILLICIT CONNECTION?

An illicit connection is the discharge of pollutants or non-storm water materials into a storm sewer system via a pipe or other direct connection. Sources of illicit connections may be sanitary sewer taps, wash water from Laundromats or carwashes, footing drains, and other similar sources.

WHAT IS AN ILLICIT DISCHARGE?

An illicit discharge is the discharge of pollutants or non-storm water materials to storm sewer systems via overland flow, or direct dumping of materials into a catch basin. Some examples of illicit discharges include the overland drainage from a carwash, or dumping used motor oil in or around a catch basin.

WHAT ARE ACCEPTABLE NON-STORM WATER DISCHARGES?

Acceptable non-storm water discharges include:

- Water line flushing
- Landscape irrigation runoff
- Diverted stream flows
- Rising groundwater
- Uncontaminated groundwater infiltration
- Pumped groundwater
- Discharges from potable water sources
- Foundation drains
- Air conditioning condensate
- Irrigation water
- Springs
- Water from crawl space pumps
- Footing drains
- Lawn watering runoff
- Water from non-commercial car washing
- Flows from riparian habitats and wetlands
- Residential swimming pool discharges and other de-chlorinated swimming pool discharges
- Residual street wash waters
- Discharges or flows from emergency fire fighting activities

PURPOSE OF THIS PROTOCOL MANUAL

The purpose of this manual is to define the procedures for the illicit discharge elimination plan. The manual will review the steps used to find and locate illicit connections/discharges including:

- Identifying outfalls
- Visiting outfalls
- Recognizing problems

- Tracking the problems upstream
- Identifying the source

The methods of storing the data and information regarding health and safety issues are also included in this appendix.

STEPS TO FIND AND LOCATE ILLICIT CONNECTIONS/DISCHARGES

The steps to finding, locating illicit connections and discharges can be grouped into four sections. Office work prior to the sampling includes locating outfalls and manholes, developing a daily work plan preparing traffic control plans, and five-day advance notice to MDOT of these plans. Prior to the site visit metrological data, equipment, calibrations and bottle supplies must be checked. A field site visit can then be made where inventories and screenings are completed and samples are collected for each outfall. Following the site visit samples must be delivered to the lab. Inventory and screening data must be to the main database after the visit, and test results entered when they are received. Figure 1 represents this step-by-step process. Additional details can be found in the subsequent chapter.

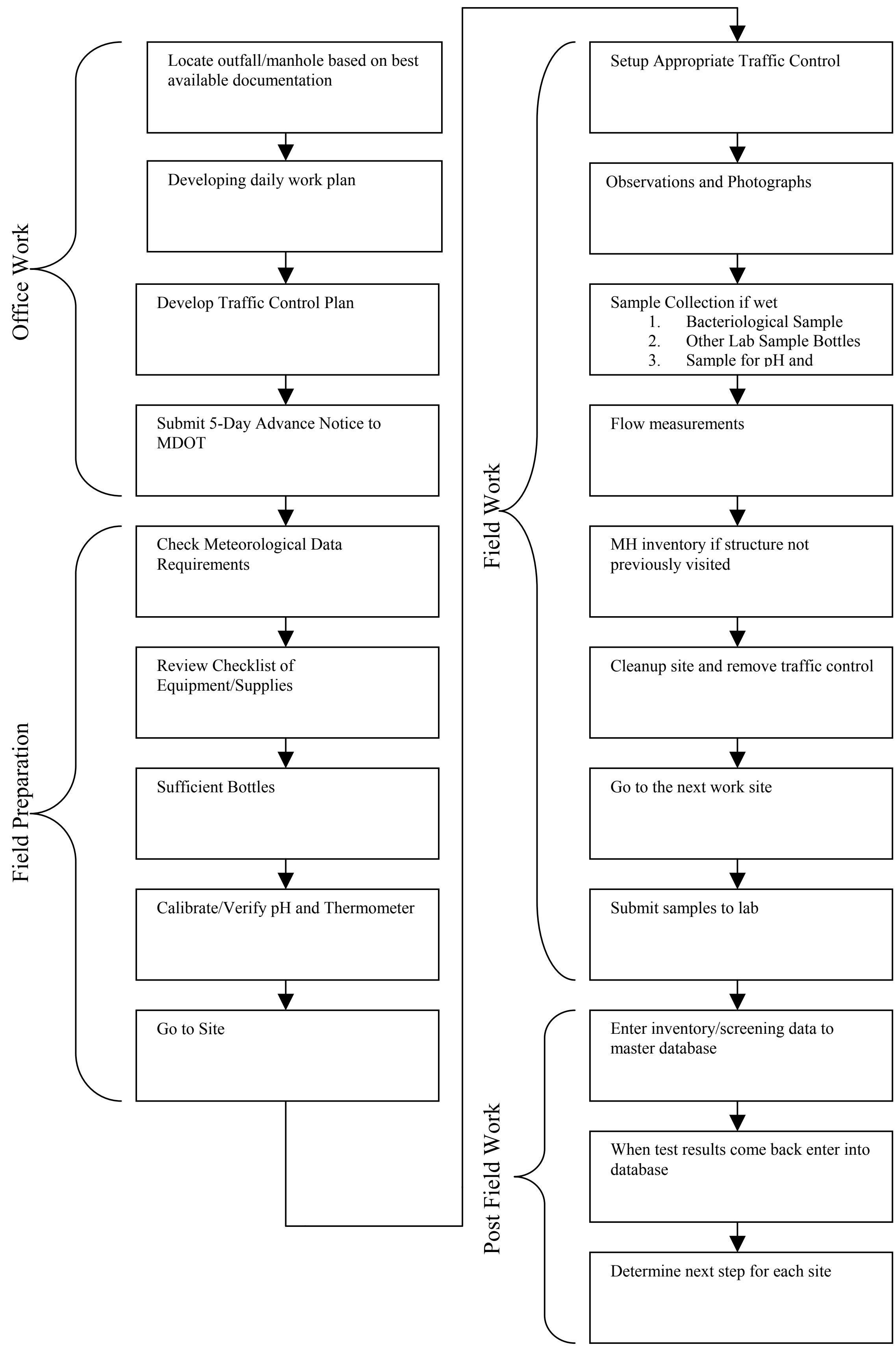
IDENTIFYING OUTFALLS

Locating Outfalls

In the permitting process, outfalls were identified by using the best data available at the time. In the implementation phase, these outfalls will need to be confirmed and any previously unidentified outfalls must be located. The following steps will be used to identify previously known and unknown outfalls.

1. Obtain the best available base map.
2. Locate on the base map all previously identified outfalls from the original permit.
3. Obtain the best available storm water system maps from any other available sources.
4. Plot the available information on base map.
5. Review on paper the locations of all known outfalls and the location of all known construction projects over the last 10 years.
6. Update the base map according to the information obtained.
7. Go into the field and walk the system verifying the location of the previously identified storm water system outfalls and visually look for any missed outfalls. During this phase of the work the field crews should look for logical locations of outfalls not already identified on the maps, i.e., and low points along the road. This step is to be performed concurrent with the field screening tasks.

Figure 1 Project Flow Chart



NOTIFICATION PROCEDURES

Prior to any work in the field, notification shall be given to the respective MDOT office on using the five-day advanced notice form. This form will require information pertaining to where fieldwork is taking place. Any work that causes an obstruction to traffic flow, e.g. lane closures, shall be worked out ahead of time with the respective MDOT office 48-hours in advance. Obstruction to traffic may be limited by time of day; day of the week and other construction related ongoing activities. A copy of the statewide permit to work within the MDOT ROW must be carried in work vehicle at all times.

VISITING OUTFALLS

When to Visit

Outfalls should be visited only during periods of dry weather in order to minimize the chance of observing storm water in the storm sewer system. As a general rule of thumb, dry weather can be defined as 72 hours of less than 0.10 inches of total precipitation.

Equipment

A list of necessary equipment for visiting outfalls is located in Appendix A.

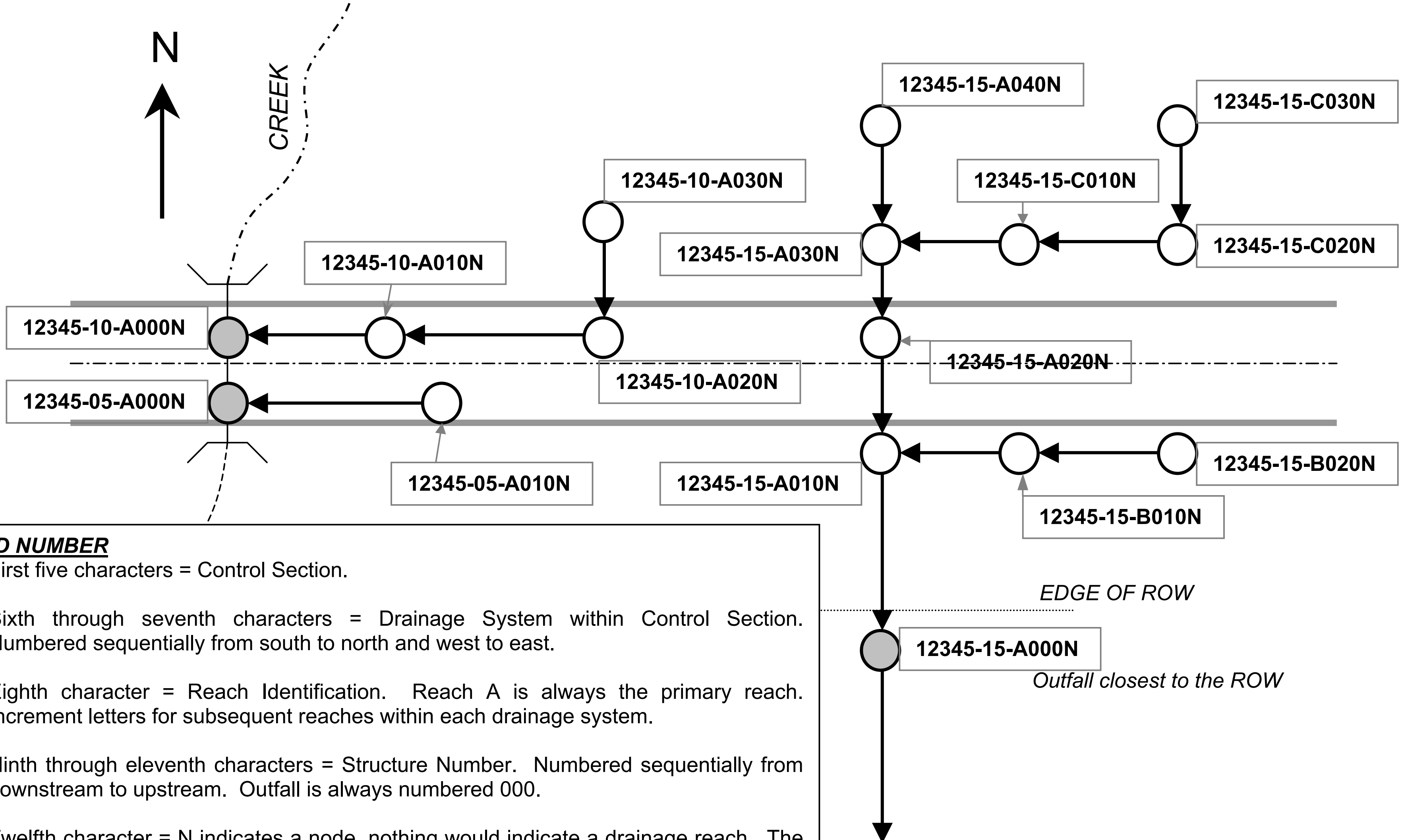
Identification Numbering

Each outfall will have a unique ID number. The purpose of the ID number is for tracking information associated with a given outfall. Each structure will be assigned an ID composed of the Control Section, the drainage system within a control section, a reach within the drainage system and a structure number. The format is described in Figure 2.

Coordinates of Outfall

Outfall horizontal coordinates will be determined within a 10-meter accuracy. This level of accuracy is sufficient for this type of work. A combination of offset distances and a handheld GPS unit with a differential receiver will be used to provide this information.

Figure 2 Example Identification Numbering



ID NUMBER
First five characters = Control Section.

Sixth through seventh characters = Drainage System within Control Section. Numbered sequentially from south to north and west to east.

Eighth character = Reach Identification. Reach A is always the primary reach. Increment letters for subsequent reaches within each drainage system.

Ninth through eleventh characters = Structure Number. Numbered sequentially from downstream to upstream. Outfall is always numbered 000.

Twelfth character = N indicates a node, nothing would indicate a drainage reach. The node on the upstream end of a drainage reach is always the same name as the reach, just with an "N" added. A node can be a manhole or any other point in the system.

Inventory

An inventory sheet will be filled out for each outfall or structure visited. Only one inventory sheet should be filled out per structure. The inventory sheet records the outfall or structure ID, the physical location, and the physical characteristics. Refer to Appendix B for the inventory form.

Screening

A copy of the field screening form is located in Appendix C. Every time an outfall or structure is visited a screening form must be completed. There are several components to conducting a screening at outfalls and structures. These include:

- General information
- Flow measurements
- Observations
- Sample analysis

General Information

The extent of collecting general information is to identify the outfall ID, the date and time of screening, the crew conducting the screening, and the weather conditions at the time of the screening.

Flow Measurements

Dry weather flow rate measurements are intended to provide an estimate of the existing flow rate. Field crews should make an initial assessment regarding the level of effort required to estimate flows. If flow measurements will require more than about 10 to 15 minutes, a description of flow and depth measurement should be provided, or an alternate flow measurement, and/or sampling point should be identified. Flow estimates should not become the primary focus of the dry weather field screening activities. Flow measurements should be performed only after a water quality grab sample is collected to avoid disturbing bottom sediments.

Three methods are outlined for estimating dry weather flow rates at field screening points. These methods include (1) measuring the time it takes to fill a bucket; (2) measuring area and velocity, and calculating flow as the cross-sectional area times the average velocity, and (3) measuring the depth, width, and slope of the channel and calculating the flow based on Manning's equation. The procedures for these methods may be referenced in Appendix D.

Observations

Observation of an outfall or structure condition is a critical component to determining the likelihood of an illicit connection to the upstream drainage system. Below is a list of observations that may suggest the existence of an illicit discharge or connection.

Floatables

The occurrence of floatables in the storm sewer system can be one of the most defining pieces of evidence. Floatables can be a variety of things including oil sheens, sewage, and sanitary trash, such as toilet paper. If sewage and/or sanitary trash are observed in the storm sewer system it is an indicator that a sanitary system is connected. Some floatables occur naturally, especially in streams and rivers. Some of these naturally occurring floatables include algae, bryozoans, pollen, and oil like sheens, which may actually be bacteria. For more information about these naturally occurring floatables see the MDEQ documents presented in Appendix E.

If floatables are observed in lakes or streams, attempt to identify a relationship between these materials and any nearby outfalls. If it appears that the floatables are originating from a pipe or outfall, it could be a sign of an illicit discharge.

Dry Weather Flow

Dry weather flow can be a valuable observation when identifying systems with potential illicit connections and discharges. Dry weather flow is flow in the storm sewer system even though it has not rained in several days. The presence of flow may suggest that there is an illicit connection or discharge. Dry weather flow may not indicate a problem if the flow is originating from any of the non-storm water discharges listed on page 2. If dry weather flow is observed, other indicators that could provide evidence of illicit connections or discharges should be looked for.

If initial field screening indicates that no flow is present, but suggests an illicit connection may be present, then a check for intermittent dry weather flow should be made. To check for intermittent flows a sandbag should be secured to a rope and lowered into position to avoid confined space entries. Position the sandbag such that it is blocking the lower part of the flow channel of the pipe in question. Secure the top of the rope to a manhole step, or similar item, for easy retrieval. Sandbags should only be left in the manhole for 1 to 2 days and never when the weather forecast is for rain. Re-visit the site within 1 to 2 days looking for signs of intermittent flow and remove the sandbags.

Odor

Strong chemical or sewage odors in a storm sewer may indicate an illicit connection or discharge. If odors are detected, one should look for other indicators including floatables, dry weather flow, watercolor, or stains inside the manhole or pipes.

Foam

The occurrence of accumulations of foam in a storm sewer system may indicate an illicit connection or discharge. Foam can be a natural occurrence in streams and lakes, but if the foam is concentrated around a storm sewer outfall, or appears to be originating from an outfall, it may be an indication of an illicit connection or discharge in that system. For more information on foam see the MDEQ document in Appendix E.

Other Indicators

Other indicators, which may not be significant by themselves, can provide valuable additional evidence to any of the above indicators. These indicators include color, turbidity, the existence of stains or deposits, and the occurrence of excessive vegetation at the discharge point.

Chemical Analysis

When dry weather flow is found, a sample of the flow is to be collected for chemical analysis. The samples are tested, at an analytical lab, for fluoride, ammonia, hardness, total organic carbon, detergents, and *E-Coli*. In the field, temperature and pH are recorded for each sample. All data is then recorded on the screening form.

Sample Collection

If the flow stream has a free fall discharge, the sample bottle may be held beneath the flow stream to fill the bottle. If this is not the case, then a disposable syringe with a pull string may be mounted on a grade rod to collect the sample. A new sterile syringe is used for each new site.

In the case where a syringe with a pull string is necessary to take a sample, the following steps should be used to ensure proper sampling. A syringe should be opened and duct taped to the end of a grade rod. The tip of the syringe must extend below the end of the rod. In order to operate the syringe, string must be tied to the pull section of the syringe and the protective cap from the syringe has to be removed. To obtain a sample, insert the grade rod into the manhole without touching any objects on the way down, such as steps, the rim, or walls. Care should be taken in collecting the water sample to not disturb any sediment. Before pulling the string to fill the syringe, make sure the string is not twisted around the rod, or the string will break. It may take several attempts to fill the bottles full; therefore the bottles must be capped after each attempt.

Three different types of sample bottles are to be filled for each outfall location visited if a flow stream exists. The bacteria test sample should be taken first to reduce contamination. The chemical parameter sample bottles should be taken second and the sample for the field-testing should be taken last.

When collecting a sample, MDEQ water analysis sample collection standards must be practiced. Do not open the bottle until ready to collect the sample, touch the inside of cap or bottle, rinse the bottle with the sample, or use an intermediate container. Make sure to fill the bottle to the bottom of the neck. Be sure each container has the correct water analysis request form associated with it and that it is attached to or in the same box as the sample bottle. Refrigerate all samples during storage prior to shipment or delivery to the lab. Complete a chain-of-custody form for all samples.

Field Testing

Temperature and pH of the water are to be measured in the field immediately after collecting a sample. The pH pen used in the field should be calibrated daily. The test pen can be calibrated by measuring a known calibration standard and adjusting the reading to correspond to the value of the known calibration standard. The calibration instructions and procedures for using the pH pen are located in Appendix G. Each time the pen is calibrated it should be recorded in the calibration log. A copy of a calibration log is also provided in Appendix G.

The thermometer used in the field should be verified daily by comparison with an office thermometer. Each time the thermometer is verified it should be recorded in the verification log. A copy of a verification log for the thermometer is also provided in

Laboratory Testing

Sample bottles from the laboratories are to be picked up prior to the screening activities. Water samples will be collected for both the chemical parameter tests and the microbiology tests where possible and sent to the respective laboratories for analysis. Samples should be kept cool until delivered to the lab. Microbiology tests have a hold time of 24 hours between the time the sample is collected and when the sample needs to be at the laboratory; therefore, appropriate planning is needed on when the samples are collected. Table 1 summarizes the chemical parameters being tested and corresponding bottle characteristics. Samples should be delivered daily to the lab and should not be stored overnight or over a weekend if at all possible.

Laboratory addresses, phone numbers and drop off times are located in Appendix H.

Table 1 Sample Parameter Information

Analyze	Test Method	Bottle Type/Size	Preservative	Hold Time
Ammonia	SM 2340C/ EPA 130.2	150 mL plastic	Sulfuric Acid (H_2SO_4)	28 days
E. Coli	EPA 340.2/300	100 mL sterile plastic	Thiosulfate	24 hours
Fluoride	EPA 350.3	150 mL plastic	None	28 days
Hardness	EPA415.1/ EPA 9060	150 mL plastic	Nitric Acid (NHO_3)	6 months
Surfactant (Detergent)	SM 5540C	250 mL plastic	None	2 days
Total Organic Carbon (TOC)	EPA 415.1/ EPA 9060	40 mL clear glass vials (2)	Sulfuric Acid (H_2SO_4)	28 days

Notes: All samples are grab samples
A total of two bottles are to be collected for TOC per site

During field visits all health and safety procedures must be followed, including the use of proper safety equipment. Notifications procedures must also be followed as stated in this document. Refer to the Health and Safety chapter for more details.

RECOGNIZING A PROBLEM

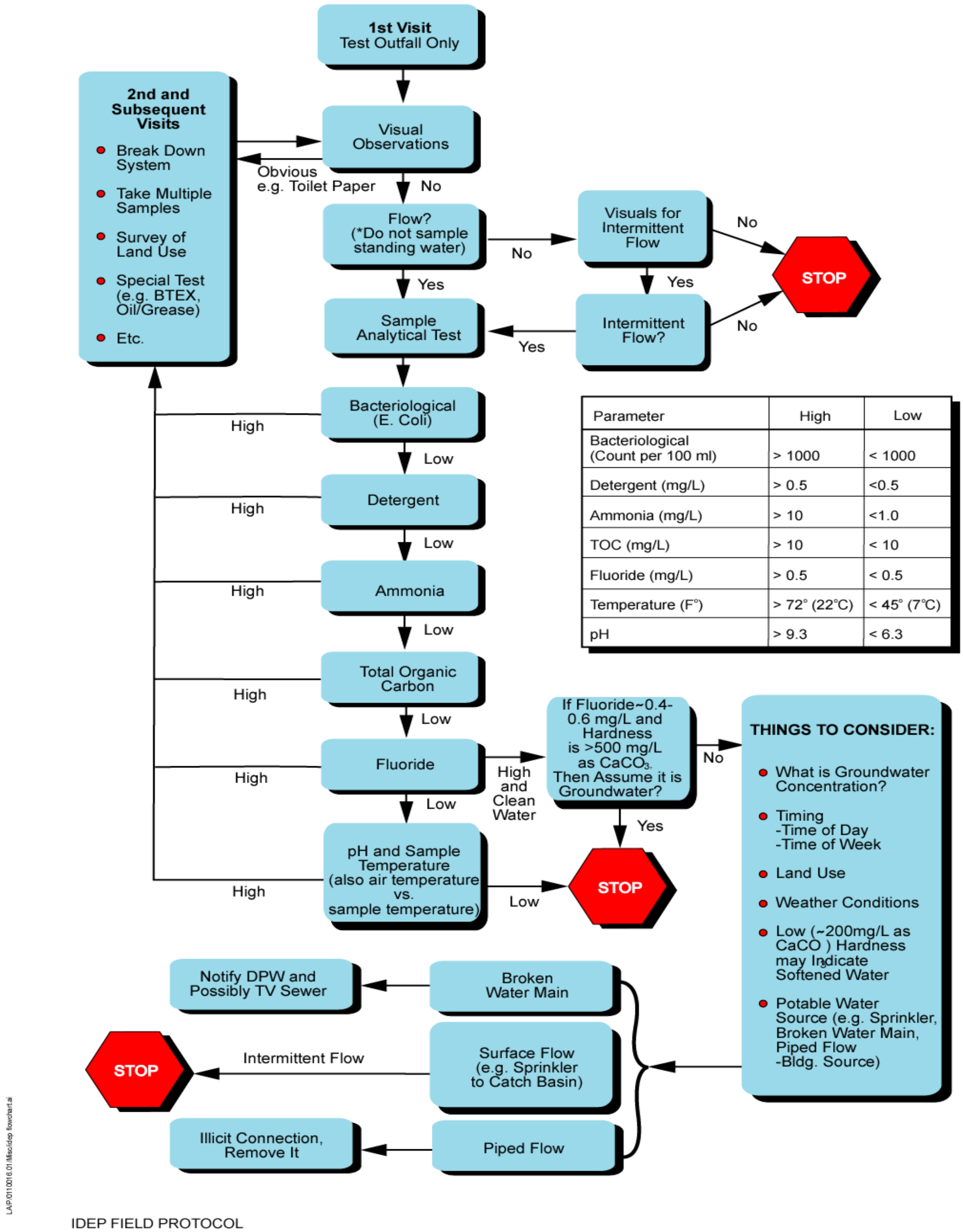
As mentioned before, when dry weather flow is present, a sample of the flow is to be collected for bacteria and chemical analysis. Once laboratory results are available they are entered into the database and a determination is made regarding the likelihood of an illicit connection or discharge. Figure 3 shows the parameter cut off limits for the chemical parameters being tested and indicates whether the sample results are out of the normal range. Figure 3 also shows the decision making process in determining the likelihood of a possible illicit connection for first and subsequent visits.

Tracking Upstream

If an illicit discharge or connection is suspected, additional investigations and tracking will be required at the outfall and within its drainage system. At each subsequent visit the outfall must be sampled. Once the outfall is sampled the dry weather flow should be tracked upstream. Additional sampling within the drainage network should be based on change in the dry weather flow rate, branches within the system, land use, and potential sources. Manhole inventories and screenings must be completed for each manhole visited. This process should be repeated until a potential illicit connection is found.

Contact MDOT immediately with any operation and maintenance issues such as plugged lines. Contact information is located in Appendix H.

Figure 3 IDEP Decision Making Flow Chart



Parameter	High	Low
Bacteriological (Count per 100 ml)	> 1000	< 1000
Detergent (mg/L)	> 0.5	<0.5
Ammonia (mg/L)	> 10	<1.0
TOC (mg/L)	> 10	< 10
Fluoride (mg/L)	> 0.5	< 0.5
Temperature (F°)	> 72° (22°C)	< 45° (7°C)
pH	> 9.3	< 6.3

SOURCE CONFIRMATION

Televising

An illicit connection can be connected directly into the manhole or can be connected into the system between manholes, where visual observations of the illicit connection cannot be made. In these instances televising the storm sewer line may be utilized. If televising is necessary the efforts should be coordinated through MDOT. This method is valuable since access to private property is not available to conduct dye testing.

All illicit connections identified and confirmed should be reported to MDOT and MDEQ immediately.

DATA STORAGE

DATABASE

All of the inventory and screening information is entered or downloaded into a database managed by Tetra Tech MPS. This database will be used to document the progress and results of the program.

TRAFFIC CONTROL

TRAFFIC CONTROL

TTMPS will control traffic control in accordance with the *Michigan Manual for Uniform Traffic Control Devices* by The Michigan State Advisory Committee and MDOT and *Traffic Control Policy and Procedures* by TTMPS.

HEALTH AND SAFTEY

PERSONAL SAFETY EQUIPMENT

Personal safety equipment should include:

- Traffic vest
- Steel toe boots w/metatarsal shield
- Hardhat
- Rubber gloves
- Leather gloves
- Safety glasses

CONFINED SPACE ENTRY

Project personnel will not conduct confined space entry.

MSDS FORMS

MSDS Forms are located in Appendix F.

Appendix A

Field Equipment

Table 2 Field Equipment List

Traffic Safety	❑ Arrow Board
	❑ Traffic Cones
	❑ Safety Vest
	❑ Truck
Inventory	❑ Data forms, clipboard
	❑ Handheld GPS with Differential Receiver
	❑ Manhole hook
	❑ Grade Rod
	❑ Survey Tape
	❑ Folding Ruler
	❑ Sledge hammer
	❑ Survey Wheel
Screening	❑ Stop Watch or a watch with a second hand
	❑ Water Marking Paste
	❑ Grade Rod Fitted for Sample Removal. Disposable syringes mounted to grade rod with pull string and duck tape
	❑ Disposable 60 ml Syringes
	❑ pH Pen
	❑ Thermometer
	❑ Sample bottles laboratory (automated partial chemistry)
	❑ Sample bottles from Health Department (microbiology)
	❑ Instrument Cleaning Supplies
	❑ Cooler
Miscellaneous	❑ Camera, flash, film, 200 ASA color
	❑ Mobile Phone and/or Pager
	❑ Flash Light
	❑ Mirror (for shining into manholes)
	❑ Marking Paint, case
	❑ Storm Drainage Maps
	❑ Phone Numbers (office staff, emergency, MDOT)
	❑ Permit to work in MDOT ROW
	❑ Business Cards and/or Field Badge
	❑ Metal detector
	❑ Spray paint
	❑ Two spades/shovels
	❑ Waders
	❑ Fluorescent dye
	❑ Corks, fish bobbers, etc.
	❑ Pencils, pens, sharpener
	❑ Daily field log to summarize activities
	❑ Truck log
	❑ Accident/ incident report form
	❑ Insurance/registration
	❑ Sunscreen and bug spray
	❑ Antibacterial hand sanitizer (waterless)
	❑ First Aid Kit

Appendix B

Outfall Inventory Field Form

DRAINAGE SYSTEM INVENTORY

GENERAL

Date __________ Time __________ ID [ ]

Crew Initials __________ Chk By: ________ Photographs: Roll #__________ Picture #'s __________

LOCATION (see back side for location sketch)

Community _________________ Control Section _____________________________

Route _________________

Latitude _________________ Determined by ❑ Handheld GPS with Diff Receiver (+/- 10m)

Longitude _________________ ❑ Other (Accuracy __________)

Offset Description: ____

____

____

Receiving Water Body ____

STRUCTURE TYPE

MDOT Outfall ❑ Yes ❑ No ❑ Unknown

❑ Manhole with piped connections

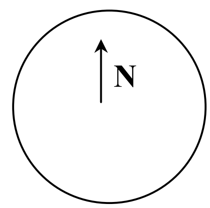
❑ Headwall connecting open channel to pipe

❑ Point within an open channel reach

❑ Pump Station Wet Well

MANHOLE INFORMATION

Direction from MH						
Sewer Size*, (mm)						
Rim Elevation						
Rim to Invert, (m)						
Invert Elevation						
Pipe Material						
Flow Depth, (mm)						



* Include appropriate dimensions and description if not circular

CULVERT INFORMATION

Shape ❑ Round ❑ Rectangular ❑ Other _________Height (mm)__________Width (mm)__________

Pipe Material ______________________________Depth of Solids in Culvert, (mm) ________________

Distance culvert invert ❑above or ❑below ditch bottom, (mm) _____________

Flow Depth in: Culvert*, (mm) ________________Ditch, (mm)___________

** measure flow depth in culvert to pipe invert, not to top of solids*

NATURAL CHANNEL CROSS-SECTION

Cross-section drawn looking downstream

Channel Material

- ❑ Concrete
- ❑ Brick or tile
- ❑ Asphalt
- ❑ Gravel
- ❑ Earth
- ❑ Rip Rap
- ❑ Vegetative –mowed grass
- ❑ Vegetative – long grass
- ❑ Other – describe

Comments____

LOCATION SKETCH

LOCATION SKETCH CHECK LIST

- ❑ Label Street Names
- ❑ Indicate North
- ❑ Locate manholes by dimensions from property lines, back of curb, edge of pavement, or centerline of road.
- ❑ Sketch catch basins and connections (no measurements necessary).
- ❑ Indicate (if possible) distance to upstream and downstream manholes
- ❑ Landmarks/nearest address, if any
- ❑ Flow direction
- ❑ Sample point
- ❑ Special access/traffic control notes
- ❑ Between mile markers _____ & _____ or _____ tenths past mile marker _____
- ❑ Velocity/depth measure location

Appendix C

Outfall Screening Field Form

DRAINAGE SYSTEM SCREENING

GENERAL ID ____________________

Date __________ Time __________ Air Temp __________ ❑Clear/Sunny

Crew Initials __________ Chk By: ___________ Rain ❑Yes ❑No ❑Partly Cloudy

Photographs: Roll #__________ Picture # __________ ❑Overcast

FLOW MEASUREMENTS

Pipe Sampled: Size (mm) ___________ Direction ___________

Depth:	❑ Dry, No Water Present	**General Data**		**Travel**	
	❑ Trace, insufficient to quantify	Depth, (mm)	____________	**Time Trials**	
Velocity:	❑ Insufficient to quantify	Dist Traveled, (m)	____________	#1 (sec)	____________
Method:	❑ Area * Velocity	Bucket Vol, (l)	____________	#2 (sec)	____________
	❑ Bucket	Channel Slope (%)	____________	#3 (sec)	____________
	❑ Manning's	Channel Material	____________	Avg (sec)	____________
Flow:	______________________________	Channel, n	____________	Vel (mps)	____________

Intermittent Flow Check
❑ Not Checked
❑ Left Sand Bag in Channel
❑ Removed Sand Bag, intermittent DWF present ❑ Yes ❑ No
if possible describe frequency, duration, time of day of flow slugs – put in comments section

OBSERVATIONS *(if "other" checked fill in description at bottom of page)*

Odor	❑None	❑Musty	❑Sewage	❑Rotten Egg	❑Gas	❑Oil	❑Other
Color	❑Clear	❑Light Brown	❑Dark Brown	❑Green	❑Grey	❑Black	❑Other
Turbidity	❑Clear	❑Slightly Turbid	❑Moderate Turbid	❑Highly Turbid	❑Opaque		❑Other
Floatables	❑None	❑Trash	❑Sewage	❑Green Scum	❑Oil Sheen		❑Other
Deposits/ Stains	❑None	❑Mineral	❑Sediment	❑Oily	❑Grease		❑Other
Vegetation	❑None	❑Normal	❑Excessive	❑Algae			❑Other
Structural	❑Normal	❑Cracking	❑Spalling	❑Corrosion	❑Settlement		❑Other

CHEMICAL ANALYSIS

FIELD ANALYSIS LAB SAMPLE COLLECTED Chem. Sample ID ______________

Bact. Sample ID______________

	Trial 1	Trial 2	
Temperature	_______	________	°C
pH	_______	________	

Chemistry

Fluoride	______________	mg/L
Ammonia (as N)	______________	mg/L
Hardness (as CaCO3)	______________	mg/L
Total Organic Carbon	______________	mg/L
Detergent	______________	mg/L
❑ E. Coli	______________	per 100ml
❑ Fecal Coliform	______________	per 100ml

Comments____

____

____

Appendix D

Flow Measurement Methods

Bucket Method

This method is typically limited to locations where there is free fall of water at the discharge point. The free fall must be high enough and concentrated along a narrow area so that a calibrated container can be positioned to collect all of the flow.

Equipment Needed:

1. Wide mouthed container(s) (bucket) graduated in known volume increments.
2. Stopwatch.

Procedure:

1. Place container under flow discharge point so that entire flow is collected.
2. Measure the time it takes to fill the bucket to a known volume.
3. Record the time duration and the volume.
4. Repeat Steps 1 through 3 at least once. Repeat steps at least twice, if the results vary by more than 20 percent.
5. Calculate the average time.
6. Compute the flow rate as follows: (Calculations to be done in the office).

   $Q = V/t$

   where:

   Q = flow rate

   V = volume

   t = time required
7. Convert the calculated flow rate to liters per second.

Channel/Pipe Measurements

The second method for estimating flow requires channel measurements. The cross-sectional area of the flowing water and velocity must be estimated. This method should be used to estimate flow rates in pipes or channels where a significant, measurable, or steady velocity is observed and cross-sectional measurements can be readily obtained. The channel measurements can be fairly accurately measured for pipes of a known diameter. However, open channel measurements will generally rely on estimates of a top and bottom width. Velocity measurements will be performed using floats and a stopwatch. Channel pipe flow calculations will be performed in the office.

Equipment Needed:

1. Depth Measurement Rod.
2. Tape Measure.
3. Float(s). These might include corks, fishing bobbers, wooden sticks, sticks and leaves, Cheerios, orange peel, or popcorn. If the float is not recoverable, then only objects that are non-objectionable in streams should be used.
4. Stopwatch.

Procedure:

1. Locate a relatively uniform section of the channel/pipe between 3 to 10 feet long.
2. Mark off a known length of the channel/pipe using available objects, such as rocks or sticks. If the site is at a manhole the diameter (typically 4 feet) of the manhole can be used as the travel length. If the outfall location is at the end of a pipe and the outfall is accessible, a yardstick can be placed into the pipe or measure the length of a pipe section with a tape measure or folding ruler.
3. Use the stopwatch to measure the time required in seconds for a float to travel the marked off distance. If conditions are windy, it is desirable to have a float that is partially submerged. The float can be inserted upstream and timed as it passes the starting point. If swirls or eddies are observed, or if the flow depth is not very deep, this technique may not be applicable.
4. Step No. 3 should be repeated at least twice. If the velocity measurements vary by more than 20 percent a fourth measurement should be performed. The measurements should be averaged after dropping any outliers.
5. Measurements to calculate the cross-sectional area of the discharge should be obtained. For flow in a pipe, measure the depth of flow and the size of the pipe (if the pipe is other than round, sufficient measurements are needed to fully describe the shape of the pipe). For flow in a natural channel, measure the depth of flow, the bottom width of the channel, and the width of the channel at the flow surface.

6. Calculate the cross-sectional area of the flow. Calculations are to be done in the office. The following equations or Table 3 (for partially filled circular pipes) may be used.

   Rectangular Pipes: area = width * depth

   Trapezoidal Channels: area = (top width + bottom width)/2 * depth

   Circular Pipes:

   $$A = \frac{d^2}{4}\left(\Theta - \sin(\Theta)\cos(\Theta)\right)$$

   $$\Theta = \cos^{-1}\left(1 - \frac{2y}{d}\right)$$

   where:

   A = Area

   d = diameter of pipe

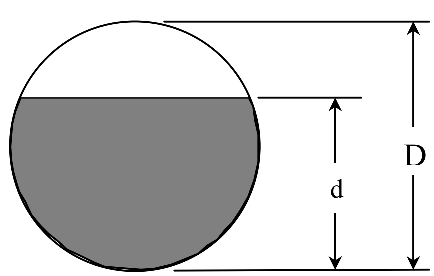
   y = depth of flow

7. Calculate the flow rate and express the result in units of liters per second. Calculations are to be done in the office.

   Flow = Area * Velocity

Table 3 Area and Hydraulic Radius for Various Flow Depths

d/D	A/D^2	R/D	d/D	A/D^2	R/D	d/D	A/D^2	R/D
0.01	0.0013	0.0066	0.36	0.2546	0.1978	0.71	0.5964	0.2975
0.02	0.0037	0.0132	0.37	0.2642	0.2020	0.72	0.6054	0.2987
0.03	0.0069	0.0197	0.38	0.2739	0.2062	0.73	0.6143	0.2998
0.04	0.0105	0.0262	0.39	0.2836	0.2102	0.74	0.6231	0.3008
0.05	0.0147	0.0326	0.40	0.2934	0.2142	0.75	0.6319	0.3017
0.06	0.0192	0.0389	0.41	0.3032	0.2182	0.76	0.6405	0.3024
0.07	0.0242	0.0451	0.42	0.3130	0.2220	0.77	0.6489	0.3031
0.08	0.0294	0.0513	0.43	0.3229	0.2258	0.78	0.6573	0.3036
0.09	0.0350	0.0575	0.44	0.3328	0.2295	0.79	0.6655	0.3039
0.10	0.0409	0.0635	0.45	0.3428	0.2331	0.80	0.6736	0.3042
0.11	0.0470	0.0695	0.46	0.3527	0.2366	0.81	0.6815	0.3043
0.12	0.0534	0.0755	0.47	0.3627	0.2401	0.82	0.6893	0.3043
0.13	0.0600	0.0813	0.48	0.3727	0.2435	0.83	0.6969	0.3041
0.14	0.0668	0.0871	0.49	0.3827	0.2468	0.84	0.7043	0.3038
0.15	0.0739	0.0929	0.50	0.3927	0.2500	0.85	0.7115	0.3033
0.16	0.0811	0.0986	0.51	0.4027	0.2531	0.86	0.7186	0.3026
0.17	0.0885	0.1042	0.52	0.4127	0.2562	0.87	0.7254	0.3018
0.18	0.0961	0.1097	0.53	0.4227	0.2592	0.88	0.7320	0.3007
0.19	0.1039	0.1152	0.54	0.4327	0.2621	0.89	0.7384	0.2995
0.20	0.1118	0.1206	0.55	0.4426	0.2649	0.90	0.7445	0.2980
0.21	0.1199	0.1259	0.56	0.4526	0.2676	0.91	0.7504	0.2963
0.22	0.1281	0.1312	0.57	0.4625	0.2703	0.92	0.7560	0.2944
0.23	0.1365	0.1364	0.58	0.4724	0.2728	0.93	0.7612	0.2921
0.24	0.1449	0.1416	0.59	0.4822	0.2753	0.94	0.7662	0.2895
0.25	0.1535	0.1466	0.60	0.4920	0.2776	0.95	0.7707	0.2865
0.26	0.1623	0.1516	0.61	0.5018	0.2799	0.96	0.7749	0.2829
0.27	0.1711	0.1566	0.62	0.5115	0.2821	0.97	0.7785	0.2787
0.28	0.1800	0.1614	0.63	0.5212	0.2842	0.98	0.7816	0.2735
0.29	0.1890	0.1662	0.64	0.5308	0.2862	0.99	0.7841	0.2666
0.30	0.1982	0.1709	0.65	0.5404	0.2881	1.00	0.7854	0.2500
0.31	0.2074	0.1756	0.66	0.5499	0.2900			
0.32	0.2167	0.1802	0.67	0.5594	0.2917			
0.33	0.2260	0.1847	0.68	0.5687	0.2933			
0.34	0.2355	0.1891	0.69	0.5780	0.2948			
0.35	0.2450	0.1935	0.70	0.5872	0.2962			



Manning's Equation

Manning's equation can be used under certain circumstances to provide an estimate of the flow rate without velocity measurements. Manning's equation requires measurements of the channel cross-section, depth of flow, and slope of the channel, and a roughness coefficient, n, must be estimated. Manning's equation should only be used where the cross-section of the channel or pipe is uniform, the slope and roughness of the channel can be estimated, where measurements are taken at the upstream end of a uniformly sloping channel and where flow discharges freely with no backwater or impoundment due to a downstream condition. Slope of the channel should either be taken off as-builts or should be surveyed.

Equipment Needed:

1. Tape measure and/or depth measuring rod.

Procedure:

1. Measurements to calculate the cross-sectional area of the discharge should be obtained. For flow in a pipe, measure the depth of flow and the size of the pipe (if the pipe is other than round, sufficient measurements are needed to fully describe the shape of the pipe). For flow in a natural channel, measure the depth of flow, the bottom width of the channel, and the width of the channel at the flow surface.
2. Additional observations should include information to determine Manning's roughness coefficient. If possible, photographs should be taken of channel to help select the Manning roughness coefficients, refer to Table 4.
3. Calculate flows using the Manning equation. All calculations are to be done in the office. The Manning equation is:

$$Q = \frac{c1}{n} A^{(5/3)} P_w^{-(2/3)} \sqrt{S}$$

Rectangular Channels

$A = by$

$P_w = b + 2y$

Trapezoidal Channels

$$A = \frac{y(b+B)}{2}$$

$$P_w = b + 2\sqrt{y^2 + \left(\frac{B-b}{2}\right)^2}$$

Circular Channels

$$A = \frac{d^2}{4}\left(\Theta - \sin(\Theta)\cos(\Theta)\right)$$

$$P_w = \Theta d$$

$$\Theta = \cos^{-1}\left(1 - \frac{2y}{d}\right)$$

where:

Q = flow (cms)

c1 = 1.0 for cmsn = Manning's roughness coefficient

A = Area (square meters)

P_w = Wetted Perimeter (m)

S = Channel Slope (m/m)

y = depth of water (m)

d = diameter (m)

b = bottom width (m)

B = top width (width at water surface) (m)

Table 4 Typical Manning's Roughness Coefficient Values

Description	n
A. Closed Conduits Flowing Partly Full	
Cast Iron	
Coated	0.013
Uncoated	0.014
Corrugated Metal	
Subdrain	0.019
Storm drain	0.024
Concrete	
Culvert	0.013
Sewer	0.014
Clay	
Vitrified sewer	0.013
B. Lined or Built-up Channels	
Concrete	
Trowel Finish	0.013
Float Finish	0.015
Finished, with gravel on bottom	0.017
Unfinished	0.017
Concrete bottom float finished with sides of	
Dressed stone in mortar	0.017
Random stone in mortar	0.020
Cement rubble masonry	0.025
Gravel bottom with sides of	
Formed concrete	0.020
Random stone in mortar	0.023
Dry rubble or rip-rap	0.033
Asphalt	
Smooth	0.013
Rough	0.016
C. Excavated or Dredged	
Earth, straight and uniform	
Clean, recently completed	0.018
Clean, after weathering	0.022
Gravel, uniform section, clean	0.025
With short grass, few weeds	0.027
Earth, winding and sluggish	
No vegetation	0.025
Grass, some weeds	0.030
Dense weeds or aquatic plants in deep channels	0.035
Earth bottom and rubble sides	0.030
Stony bottom and weedy banks	0.035
Cobble bottom and clean sides	0.040
Channels not maintained, weeds and brush uncut	
Dense weeds, high as flow depth	0.080
Clean bottom, brush on sides	0.050

* Source: Open-Channel Hydraulics by Ven Te Chow, Ph.D. 1959

Appendix E

MDEQ Fact Sheets

Appendix F

MSDS

Appendix G

Instructions and Calibration Log

pH

Pocket Pal pH Tester

Range: 0 – 14 pH units

Procedure

1. Turn on unit.
2. Remove protective cap from the bottom
3. Immerse the bottom of the Pocket Pal 1 to 3-1/2 inches into the sample.
4. Using the Pocket Pal, gently stir the sample for several seconds. After stirring and when the digital display stabilizes, read the pH value.
5. Rinse the bottom of the Pocket Pal and replace the protective cap.
6. For faster response and longer tester life, place several drops of DI water in the protective cap to prevent the glass bulb from drying out between uses.

Calibration

1. Prepare a pH 7.00 and a pH 4.00 or 10.00 buffer solution.
2. Measure the pH using the tester.
3. If necessary, adjust the Calibration Trimmer (small screws on back) until the reading corresponds to the pH of the buffer.

Notes

- Soak the electrode tip in tap water for a few minutes each week to condition the electrode.
- If pH readings become erratic, replace the batteries.
- Potassium chloride, used as a reference solution electrolyte, may deposit on the tester as a white precipitate. Although the precipitate is normal and does not affect performance, it may be removed with a damp cloth or tissue.

Table 5 Calibration Log

Date	Person	Certified Thermo-meter Reading	Field Thermo-meter Reading	Thermometer ID/pH Instrument ID	Reference Standard (name and concentration)	Instrument Reading against Reference Standard		Comments
						Before Calibration	After Calibration	

Appendix H

Contacts

Refer to Chapter 11 of the Storm Water Management Plan for contact information